AN EXPERIMENTAL STUDY AND ANALYSIS OF TIME STUDY SKILL RATING ABILITY AND THE DEVELOPMENT OF PROCEDURE FOR IMPROVEMENT

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ABSTRACT

The present time study technique requires engineers to apply motion study and to standardize the method prior to the taking of the time study. Thus in the matter of rating, speed alone is concerned. However, circumstances have forced engineers to compromise in actual studies, and to rate both speed and skill.

In an effort to investigate the ability of rating skill, two operations that exist in factories were simulated in a laboratory. Methods were standardized and certain deviated methods planned. A small group of time study engineers from the Atlanta area were the subjects of the study. In the first series of tests, engineers rated and times one operation, and then they rated the same operation while timing was done independently by the method of transcribed time study. In the second series of tests, engineers rated an operation only, and assigned one rating as in the conventional time study. Then they rated the same operation, but instead assigned two ratings to a cycle, one for the deviated portion and the other for the non-deviated portion.

A statistical analysis was applied to the results obtained. Standard deviation and systematic error of ratings were calculated for each engineer and also for the group. Trend lines for each engineer were drawn, and an analysis of variances was applied.

The results of the above-mentioned analysis showed that an engineer's ratings, when timing and rating are both required, are different

from those when rating only is required. It is also indicated that the consistency and accuracy of an engineer's rating are slightly better when rating only is required than when timing and rating are required. These engineers also rated the low ratings too high and the high ratings too low. Separating the deviated portion of a cycle from the other portion of that cycle did not result in better consistency and accuracy of rating. This, however, should be considered along with the fact that engineers are more familiar with the conventional method of rating than with the two-rating method tried in this study. The writer does not feel qualified to evaluate, from the results of this study, rating ability in relation to elemental length. He suggests that further study of this problem be conducted and also that a scale which will guide time study engineers to rate accurately be developed.

CHAPTER I

INTRODUCTION

Since the development of time study by Frederick W. Taylor, it has grown into one of the most elaborate branches of the field of Industrial Engineering. This is no doubt because time study is so well-defined and has in it so much of the scientific. But under the discipline of science nothing can be regarded as perfect, and the field of time study has much room for further research.

As a result of its scientific qualities, the majority of the various phases of time study, at present, are concerned with mechanical devices and mathematical formulas. However, there remain still some parts of time study that either involve human judgment or can not be done mechanically at present. Among them the rating procedure is probably the most pronounced. Various researches have been conducted in an attempt to reduce the magnitude of the error due to human judgment or to eliminate it entirely from the scene.

The development of synthetic time study represents a forward step in this direction. The use of compiled standard data provided more accurate standards by eliminating rating by time study men on the production floor. It should be noted that rating and leveling are still involved in compiling standard data, though in this case they are executed with painstaking care and precaution.

It is unfortunate that there is no other way to establish a time standard for an operation without having the judgment, in the form of rating or leveling, of time study men enter into the process.[1] The only way to improve the accuracy of a standard is through improving the rating ability of time study engineers. A bibliographical search revealed great concern amongtime study experts regarding the matter of rating, and various means of improving rating ability were suggested.

Jones stated that the advantage of transcribed time study is "that the time study man can keep his attention 100% of the time on the employee. In stop watch study he is actually watching the employee only a fraction of the time."[2]

Most experts realize that the time study man finds it difficult to take a conventional time study because he is called upon to evaluate the operator's performance, read a stop watch, and record the watch reading and the rating. Barnes recognized the fact that while rating each element in stop watch time study, the time study man will have considerable difficulty in making an accurate appraisal unless the elements are fairly long.[3] This difficulty and the inaccuracy thus introduced will become critical if the elements or cycle are short, as the percentage of error in reading a decimal-minute stop watch increases alarmingly as the elemental duration decreases from 0.1 minute.

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[1]Barnes, R. M., Motion and Time Study (New York: John Wiley & Sons, Inc. 1949) p. 352

[2]Jones, Wilber D., "And Now - Recorded Time Studies" Factory Management, No. 108, March 1950 p. 126

[3]Barnes, R. M., Motion and Time Study, pp.348-349

Barnes also suggested a simple technique for time study men to improve their rating ability, as follows:

> By standing in the proper position relative to the work being observed, and by holding the board so that the dial of the watch falls in the line of vision, the observer can concentrate more easily on the three things demanding his attention, namely, the operator, the watch, and the observation sheet.[4]

Mundel realized the need of a better timing process. He said,

> With the demand for increased accuracy of standards it remains to be seen what the trend will be, inasmuch as both the time study machine and camera offer considerably more opportunity for accuracy, particularly with small elements. Also both have the tendency to ease the most difficult phase of time study, that of rating, by reducing the amount of attention required for recording the time values.[5]

Morrow stated that there are two divisions in adjusting actual time study values to the level of a normal operator. One is leveling and the other is performance rating. In leveling, the causes which produce differences in production are analyzed; this analysis is applied to both skill and effort, and also to condition and consistency. But in performance rating the speed alone is concerned.[6]

Skill may be defined as proficiency in following a given method.[7] The skill of an operator is influenced partly by natural ability and partly by his experience or practice. The higher the skill possessed by an operator, the faster the possible pace before muscular coordination fails.

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[4]Barnes, op. cit., p. 338.

[5]Mundel, Marvin E., Motion and Time Study Principles and Practice (New York: Prentice-Hall, Inc. 1950), p. 308.

[6]Morrow, Robert Lee, Time Study & Motion Economy (New York: Ronald Press Co., 1946), p. 114.

[7]Lowry, S. M., Maynard, H. B., Stegemerten, G. J., Time & Motion Study (New York: McGraw-Hill Book Co. 1940), p. 207.

All the suggestions and remarks from investigators in the field of time study are, so far, concerned with the shortcomings of the stop watch. No investigation could be found which studied skill rating ability and the effect of using a stop watch on the time study engineer's rating ability.

The different effect of using repetitive (snapback) or continuous timing processes has little or no significant bearing on the investigation in this thesis, since the time for reading a watch and recording this reading is the same for both methods. However, it is interesting to note that the use of the continuous timing method has shown a less mean error than the snapback method when the elemental endings in an operation need constant visual attention because the lack of distinguishable sound indicating the ends.[8]

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[8] Lazarus, Irwin P., "The Nature of Stop Watch Time Study Errors" Advanced Management, May 1950. p. 15

CHAPTER II

THE PROBLEM

The rating of an operator's performance is generally regarded as the rating of the speed or pace at which the operator performs the job. But frequently time study men rate skill as well as speed. In some cases it is extremely hard to determine whether vagueness of variations is due to deviation of method or to change of speed, and this difficulty has caused time study men to overlook minute details and give an overall rating. Gard stated that some time study men appear to rate skill and speed in some instances.[9] Presgrave, in discussing leveling, also said that time study men rate speed and skill either knowingly or unwittingly in some instances. He also suggested that circumstances may force time study men to compromise at times. To quote him: "In any event, it is rare indeed to find an operation in which motion study has been so completely applied that all motions, hesitations and fixations have been standardized and become established practice prior to rate setting."[10]

The problem that prompted the writing of this thesis can be divided into two parts. One is to evaluate skill rating ability when using the customary technique of stop watch time study and the improvements (and if

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[9] Gard, O. W., "An Experimental Study and Analysis of Time Study Rating Abilities as Affected by the Stop Watch." (Atlanta: Georgia Institute of Technology)

[10] Presgrave, R., Dynamics of Time Study, (New York: McGraw-Hill Book Company, Inc. 1945)

any, to what extent), of skill rating ability can be gained by relieving time study men from reading a watch with the method of transcribed timing.[11] To be more specific, it can be stated that the aim is to investigate the differences between the consistency[12] and accuracy[13] of skill rating ability in customary stop watch time study and the consistency and accuracy of rating when timing is taken from time study men and is performed independently by a machine.

The second part of the problem is to find out whether one rating should be assigned to a cycle when deviation of method occurred within that cycle; or whether two ratings should be assigned to that cycle, one for the deviated portion and the other for the non-deviated portion.

The idea of assigning two ratings is open to challenge. The writer does not conduct this investigation to defend this idea, but hopes only to make an appraisal from the result of his findings.

The present practice of time study technique requires the time study man to apply motion study and to standardize his method prior to timing and rating, and also requires him to time a foreign element if one occurs. This is a sound procedure and the delay caused by a foreign element can, by this method, later be excluded from the cycle. But, as previously quoted in this thesis, Presgrave has pointed to the fact that the application of motion study is rarely complete or perfect. It is likely

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[11]Jones, W. D., "Transcribed Time Studies," The Research Engineer, (Atlanta: Georgia Institute of Technology) January 1950. p. 5

[12]Consistency means identical performances are rated the same every time.

[13]Accuracy means any performance is rated at its true value.

that between these two extremes of complete application of motion study and presence of foreign elements, the time study man will encounter frequently minor deviations of method while taking a time study on the production floor. If the job being studied is highly repetitive, then he can exclude those cycles containing deviations and still have plenty of valid cycles for calculating normal time. If, on the other hand, he is restricted by the nature of the operation being studied or a peculiar production pattern in which only a small number of cycles can be studied, then he would have to use all the cycles he has in calculating normal time. Realizing the restricting circumstances in actual production studies, time study men have compromised and rated both speed and skill in some instances.

CHAPTER III

PROCEDURE

In obtaining data, a simulated factory operation was set up in the laboratory. A group of practicing time study engineers were the subjects of the study. They were shown, prior to each test, demonstrations of the operation to familiarize them with the standard method and the elemental ends. Three series of tests were conducted. The first series was designed to obtain the normal time of each element of the two operations studied in this investigation. The second series was for the purpose of studying the difference in rating ability of the engineers. The third series of tests was for the purpose of studying rating methods.

Selection of Operations The selection of an operation has some restrictions. First of all, the operation must be capable of being simulated in a laboratory. Then, in order to be realistic, it should be an operation that actually exists in a factory. It is very desirable to have a repetitive operation with a cycle duration of not more than several minutes. It is also helpful to have a pure manual operation requiring simple skill to perform it properly. And finally, the operation should be sufficiently familiar that it can be understood readily by any time study man.

After considering the above restrictions, two operations were chosen. The assembling of a small dolly was chosen to be time studied on an elemental basis for the first part of the problem. This operation is designated hereafter as operation A. The assembling of a medium size wire rope clip was rated on a cycle basis for the second part of the problem, and is designated hereafter as operation B. Appendix II shows the elemental breakdown and also left-hand and right-hand descriptions of the standard methods. The layout of work places and the positions of the operator are shown in Appendix VI. Appendix III shows a discription of the contents of planned method deviations and also the sequences of deviation the operator followed during tests 2 and 3, and those during tests 4 and 5.

Timing Device Besides the stop watch that was used by time study engineers when so instructed, a trained timer made transcribed timing throughout all tests. An adapted standard portable magnetic wire recorder was the timing device. In recording, the wire recorder was turned on before the start of timing. As the fine wire was drawn through the magnetic recording head at constant speed, the timer spoke into the microphone all information he thought would be useful. At the beginning of a cycle and also at the end of all elements he would tap on the back of the microphone with a tapper worn on the forefinger of the hand holding the microphone. Later, while playing back the recorder, each tap would produce a sharp sound accompanied by a simultaneous flash of the neon indicator on the wire recorder. The duration of elemental occasions was measured by converting into time the distance between two successive taps on the recorded wire. This was accomplished by coupling an adapted revolution counter to the take-up pulley of the recorder. This arrangement proved to be feasible to measure up to 0.001 minute.[14] Figure 17 shows

[14] Jones, "Transcribed Time Study," p. 5.

a close-up of an adapted wire recorder, and the making of the transcribed time study.

Collecting the Data Five time study engineers from the Atlanta area were the subjects of these tests. All engineers have had two or more years of experience in time study. All but one designated 100% as normal, the remaining engineer designated 60 points as normal. A student with average dexterity was trained as operator, and there was approximately ten hours of practice prior to each test. Half of this practice was taken immediately before each test with one hour of rest between test and practice. The other half of the practice was taken the day before the test was given.

In test 1, which was designed to obtain normal time for operation A and operation B, the operator was to follow the standard method and vary the speed intentionally within the range of 80% to 120% from cycle to cycle, but to let the variation of speed within a cycle be unintentional. The engineers rated both operation A and operation B on an elemental basis.

In both tests 2 and 3, the operator followed the standard method, and then introduced planned method deviations, with regard to contents and sequence of deviations, as shown in Appendix III. He strove to work close to 100% speed. Test 3 is merely a duplicate of test 2 as far as the operator is concerned. The engineers timed and rated each element in test 2, and for test 3 they rated each element only.

Tests 4 and 5 required the operator to follow the standard method or to introduce deviations as shown in Appendix III. He strove to work close to 100% speed and make test 5 a duplicate of test 4 as best he could. The engineers assigned one overall rating to each cycle in test 4; and gave two ratings to each cycle in test 5, one for the deviated portion and the other for non-deviated portion of that cycle.

Since these two operations would be continuous repetitive jobs in a factory, it is desirable that they be performed continuously in the laboratory. But the operator was instructed to pause at the end of each cycle to provide time for the engineers to record their ratings. Therefore, the operator was instructed to repeat the last element and proceed into the next cycle without any interruption. This is necessary in order to keep the motion of the operator's arms in correct rhythm while entering the next cycle.

Each engineer was furnished with a decimal-minute stop watch mounted on a time study board, observation sheets with elemental endings printed on them, and descriptions of standard methods.

Before each test, the objective of the test and the procedure in taking it were explained. Demonstrations of standard methods were given and elemental endings discussed. In addition, the engineers were asked to:

(1) Rate each element in test 1 for both operations, rate each element in tests 2 and 3, and rate the cycle in tests 4 and 5.

(2) Not record a rating when not sure of it or when a considerable part of an element was missed.

(3) Use the elemental breakdown as shown on their observation sheets.

(4) Not rate the repeated last element when the operator is recovering his rhythm.

(5) Use whatever designation of rating was the accustomed, either

100% or 60 as normal, but to use the same designation throughout all tests.

(6) In rating operation B in test 1, memorize his elemental ratings and record them at the end of the cycle when the operator paused. The same applied to tests 4 and 5 but in them the engineers were asked to rate the cycle only.

(7) Record ratings during the operation, for operation A only, but to do this quickly so that a minimum of interruption is experienced.

(8) Use stop watch only when so directed.

(9) Use continuous method to time elements in a cycle but to snap back the watch at the end of a cycle.

(10) Strive to make each rating to the best of their knowledge and keep as much attention on the operator as possible.

(11) Refrain from checking ratings among themselves during the tests.

A timer was operating a magnetic wire recorder to time each element throughout all tests. After each test, observation sheets were collected and blank sheets distributed for the next test, to keep the engineers from referring to previous ratings.

CHAPTER IV

TECHNIQUES FOR ANALYZING RESULTS

Two techniques were used in analyzing the data. One was that of plotting the systematic error and standard deviation of the errors for ratings assigned by time study engineers against elemental lengths. Also the trend lines of ratings by each engineer were plotted. The second technique was a factorial analysis of variances.

In the first technique, the analysis was done on elemental basis for operation A and on a cycle basis for operation B. Systematic error is the algebraic average of the percentage error of each rating assigned by an engineer. The percentage of error for each rating of an engineer was calculated from the following equation:

$$\% \text{ Error} = (R_E - R_A) \div R_A$$

where R_E is the rating assigned by the engineer and R_A is the computed actual rating for that occasion. The percentage of error is calculated for every rating made by an engineer. The standard deviation for percentage of error of rating was found from the equation,

$$\sigma = \sqrt{\frac{\sum x^2}{n} - \bar{X}^2}$$

where σ is standard deviation, x denotes percentage of error, and $\bar{X}$ is the systematic error or, in other words, the mean of percentage of error, and n denotes the number of these errors (which is equal to the number of ratings). The actual rating was found by dividing the actual time of that elemental occasion by the elemental normal time.

Having calculated the percentage of errors, the systematic error of ratings and the standard deviation of errors, it becomes feasible to show graphically, for operation A, the relations between elemental length and each of the following: ratings assigned by engineers when using a stop watch, ratings assigned when not using a stop watch, ratings assigned to those occasions in which there was a method deviation and to those without method deviation. For operation B, the relation between assigning one overall rating and assigning two ratings, one for the deviated portion of a cycle and another for the non-deviated portion of that cycle, can also be expressed graphically.

Graphs were prepared showing along the abscissa the elemental length and on the ordinate the percentage of error in rating. A short horizontal line was to represent the systematic error and a vertical bar equal to two standard deviations in length was centered on the systematic error. The plotting of trend lines was applied to both operations. It was done on an element basis for operation A, and on a cycle basis for operation B. Graphs were drawn showing along the abscissa the actual rating and on the ordinate the engineer's rating. A forty-five degree diagonal from the origin represented the true rating line. By using the method of least square,[15] a trend line for a set of ratings was drawn. A solid trend line represented, in operation A, rating with a stop watch or in operation B,

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[15]Croxton, F. E., Cowden, D. J., Applied General Statistics (New York: Prentice-Hall, Inc. 1939), pp. 399-404.

assigning one overall rating to a cycle. A dotted trend line represented rating without a stop watch in operation A, or assigning two ratings to a cycle in operation B.

The analysis of variances[16] was applied to both operations in an attempt to determine (1) the variation of ratings caused by the four main factors in operation A and to what extent each of them caused the variation, and (2) the variation of ratings caused by the two main factors in operation B and also to what extent each of them caused the variation. The four factors in operation A were (1) the time study engineers, (2) the elements, (3) whether or not deviation was introduced, and (4) whether or not the watch was used. The two factors in operation B were (1) the time study engineers, and (2) the methods employed in rating a cycle.

The analysis of variances is a procedure by which the sum of squares is calculated for (1) the effect of each main factor, (2) the first order interaction between these factors, and (3) the second order interactions between these factors. The sum of squares for each main factor and interactions was divided by their degrees of freedom to form the mean squares. These mean squares were used to form ratios of variance with the residual variance, and these ratios were tested for significance by the Fisher Z test.

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[16]Brownlee, K. A., Industrial Experimentation (London: His Majesty's Stationery Office, 1949), pp. 86-102.

CHAPTER V

RESULTS OF TESTS

From test 1, the normal time for each element of operation A and for the cycle of operation B was determined and is shown in Appendix IV. The actual rating for an elemental occasion or a cycle was determined by dividing the actual time into the normal time. The actual rating was later compared to the rating assigned by an engineer for that particular occasion. The percentage of error in rating was thus calculated, and the average of the percentage of errors formed the systematic error.

The equivalent overall rating for each cycle in test 5 was calculated as follows: Assume an engineer rated the deviated portion of a cycle 80% and the non-deviated portion of that cycle 100%. The actual time of the deviated portion is 0.294 minute and that of the non-deviated portion is 0.706 minute. Then

$$0.294 \times 80\% + 0.706 \times 100\% = 94.12\%$$

Therefore, 94.1% is the engineer's rating for that cycle.

The first element in operation A does not contain method deviation, so it was excluded from comparison and analysis. The systematic errors and standard deviations for operation A, shown in Tables 1 and 2, were plotted and are shown in Figures 1 through 4. Similarly, systematic errors and standard deviations for operation B, shown in Table 3, were plotted and are shown in Figure 5.

TABLE 1

SYSTEMATIC ERROR AND STANDARD DEVIATION OF % RATING ERROR

FOR OPERATION A

TEST 2 - WITH WATCH

Element Number	Engineer A: Systematic Error, Has dev.	Engineer A: Systematic Error, No dev.	Engineer A: Standard Deviation, Has dev.	Engineer A: Standard Deviation, No dev.	Engineer B: Systematic Error, Has dev.	Engineer B: Systematic Error, No dev.	Engineer B: Standard Deviation, Has dev.	Engineer B: Standard Deviation, No dev.
2	-15.11	-6.4	10.21	5.06	-21.97	-25.67	6.51	3.71
3	-2.11	3.31	8.16	7.66	-18.58	-13.37	5.06	5.68
4	17.1	-0.2	14.3	10.09	15.18	-3.83	8.98	15.02
5	-16.1	-17.28	6.03	3.71	-29.63	-31.73	6.82	7.83
Average	-4.05	-5.14	6.67	6.13	-13.75	-18.65	6.84	8.06

TABLE 2

SYSTEMATIC ERROR AND STANDARD DEVIATION OF % RATING ERROR

FOR OPERATION A

TEST 3 - WITHOUT WATCH

Element Number	Engineer A: Systematic Error		Engineer A: Standard Deviation		Engineer B: Systematic Error		Engineer B: Standard Deviation	
	Has dev.	No dev.	Has dev.	No dev.	Has dev.	No dev.	Has dev.	No dev.
2	-10.07	2.64	5.75	4.28	-17.65	-4.65	5.97	6.33
3.	-1.07	-2.01	7.94	5.25	12.42	-0.62	12.6	2.98
4	14.1	-6.44	7.7	7.6	27.02	0.54	9.41	8.05
5	-14.37	-7.44	3.16	6.33	-9.76	-5.33	8.08	9.2
Average	-4.1	-3.31	6.14	5.86	3.03	-2.51	9.01	6.64

TABLE 3

SYSTEMATIC ERROR, AVERAGE ABSOLUTE ERROR & STANDARD

DEVIATION OF % ERROR

FOR OPERATION B

	Engineer A	Engineer B	Engineer E
Test 4 - one rating:			
Systematic Error	-0.64	5.23	-4.92
Standard Deviation	7.4	9.9	7.53
Ave. Absolute Error	5.56	9.32	7.79
Test 5 - two ratings:			
Systematic Error	-9 97	-7.36	-10.08
Standard Deviation	10 2	8.5	8.7
Ave. Absolute Error	11.34	9.2	10.88

	Test 4	Test 5
Ave. Systematic Error	-0.11	-9.14
Ave. Standard Deviation	8.28	9.13

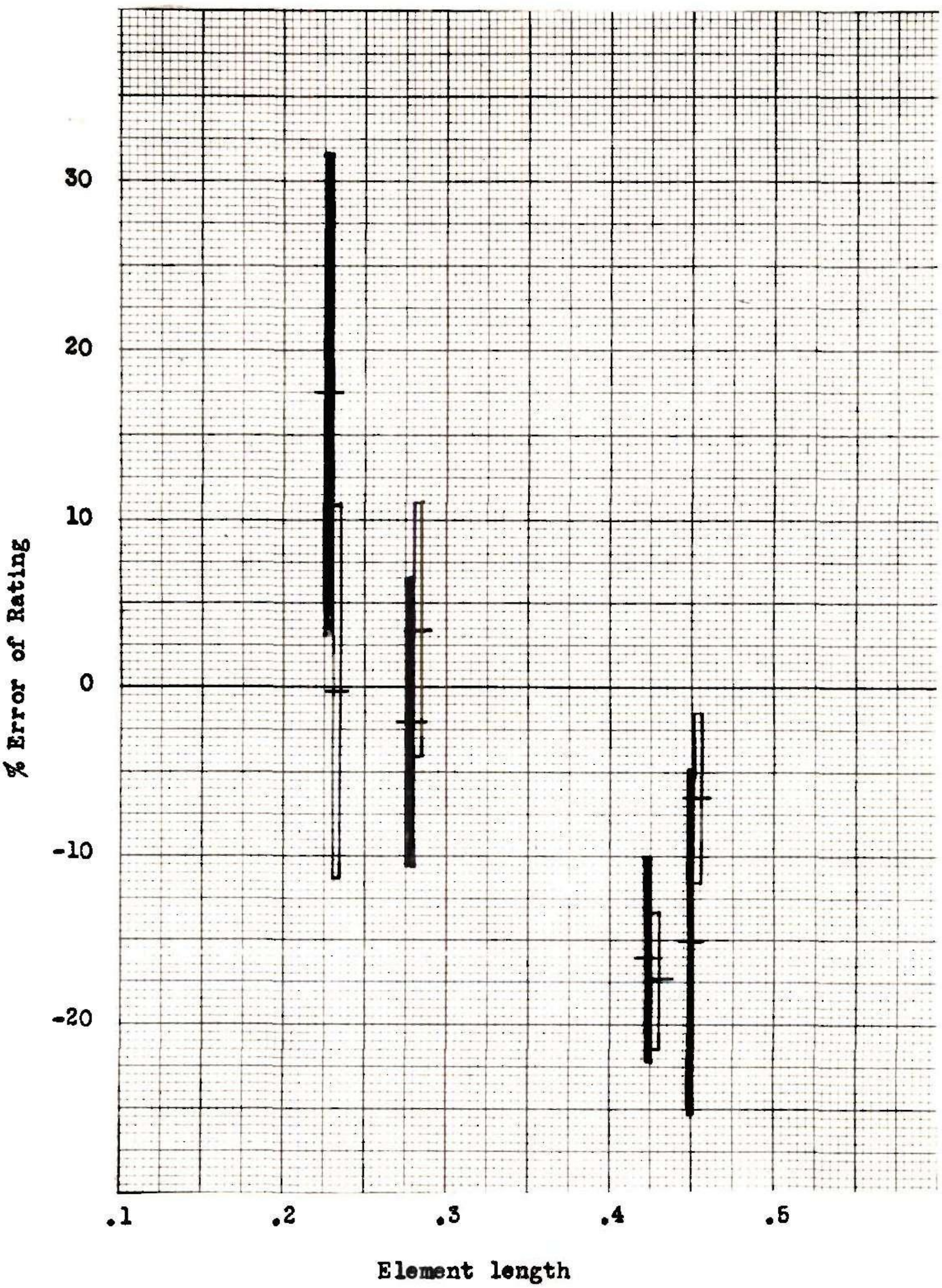

FIGURE 1. SYSTEMATIC ERROR & STANDARD DEVIATION OF ENGINEER A OPERATION A, TEST No. 2 (with watch)

Systematic Error ± one S. D., with method deviation
Systematic Error ± one S. D., without method deviation

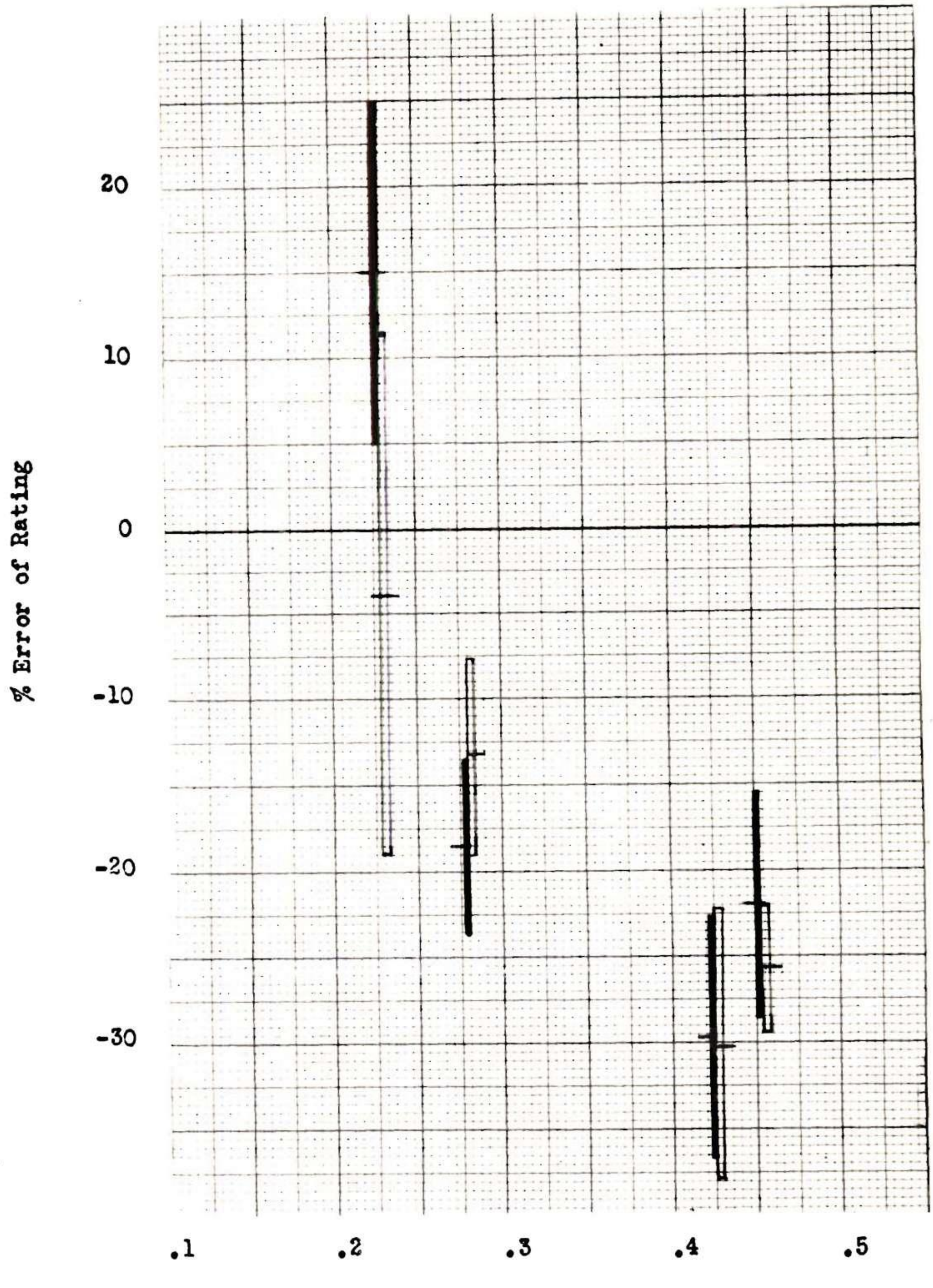

FIGURE 2, SYSTEMATIC ERROR & STANDARD DEVIATION OF ENGINEER B OPERATION A, TEST No. 2 (with watch)

Systematic Error ± one S. D., with method deviation
Systematic Error ± one S. D. , without method deviation

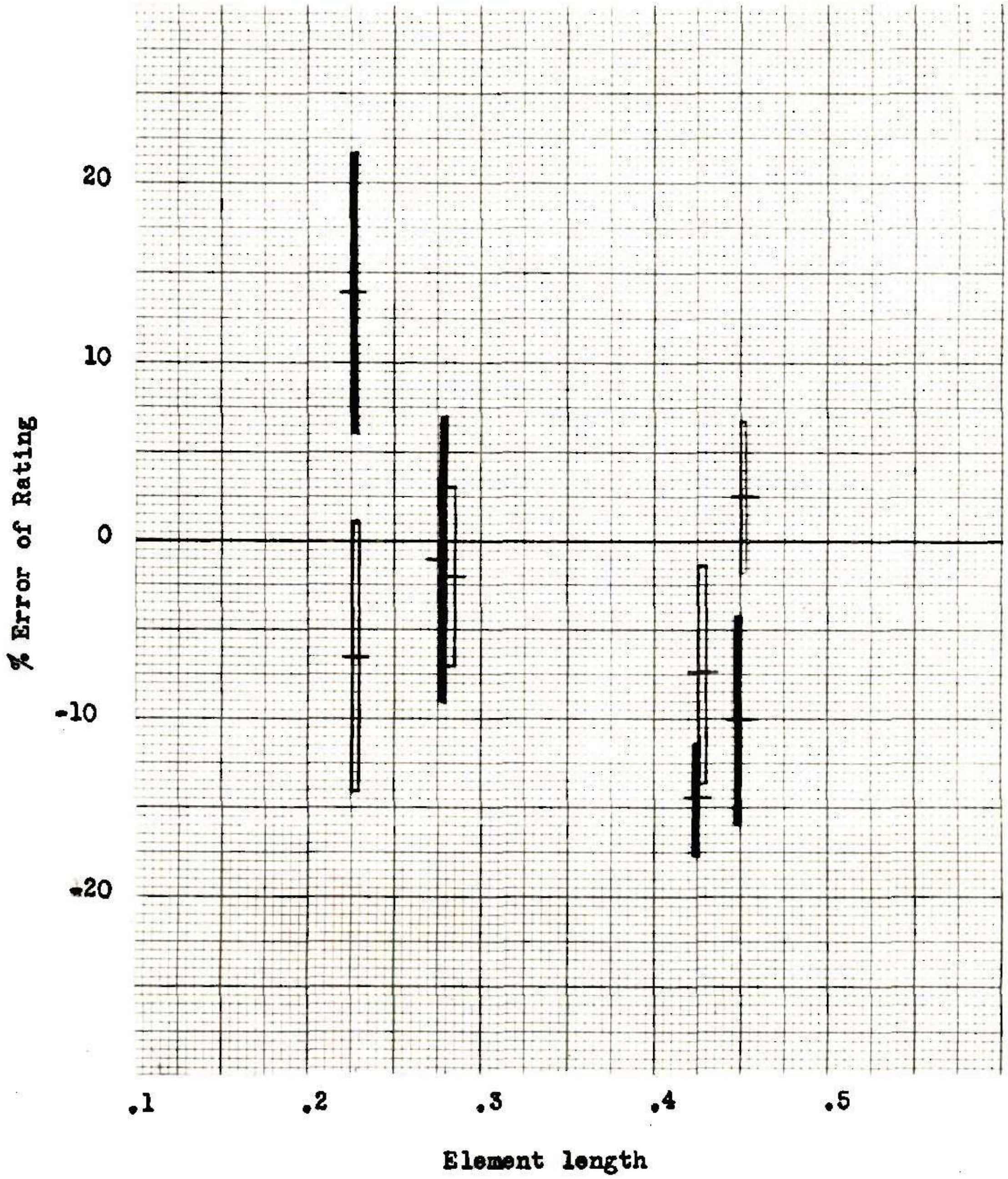

FIGURE 3. SYSTEMATIC ERROR & STANDARD DEVIATION OF ENGINEER A OPERATION A, TEST No. 3 (without watch)

Systematic Error ± one S. D., with method deviation
Systematic Error ± one S. D., without method deviation

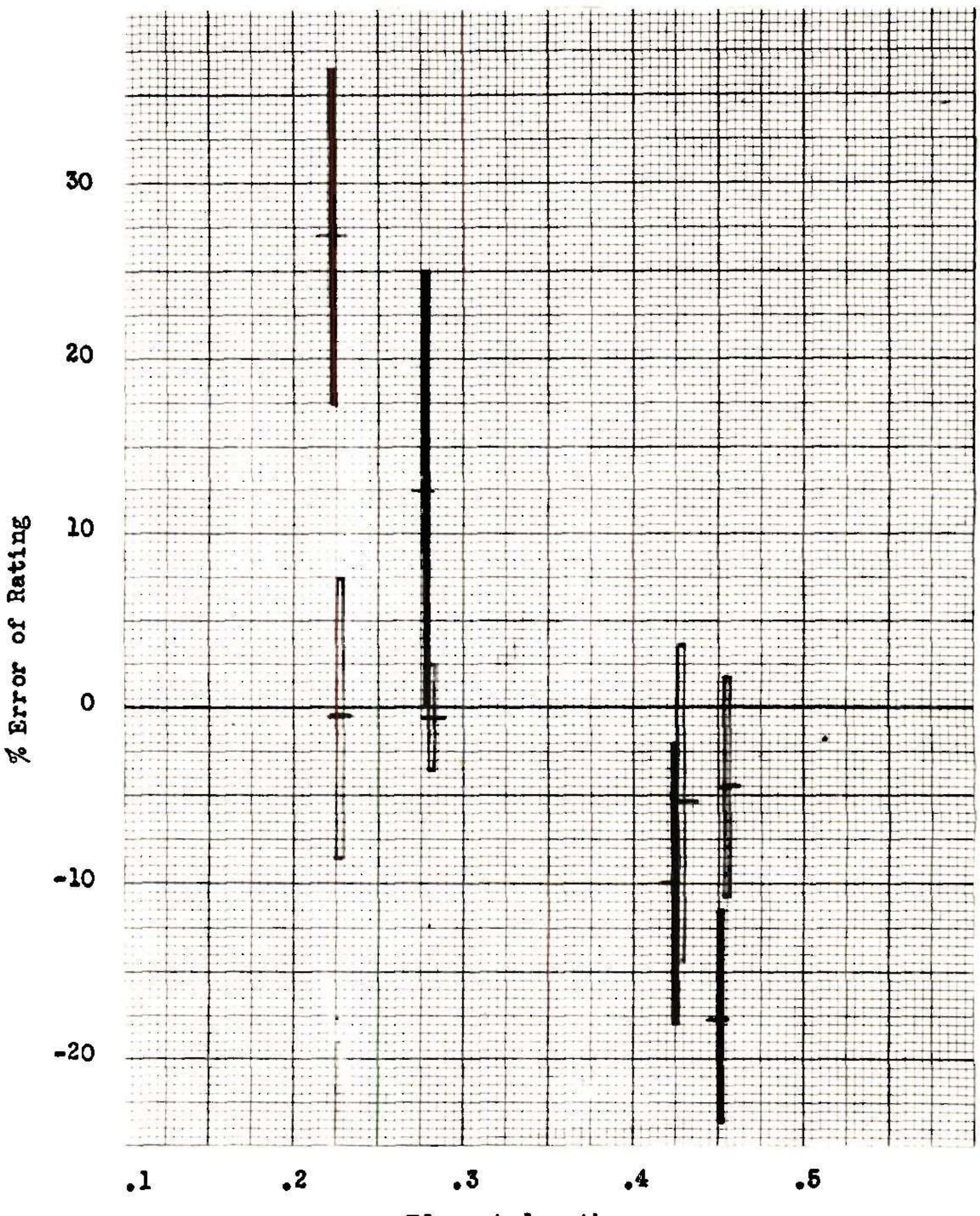

FIGURE 4, SYSTEMATIC ERROR & STANDARD DEVIATION OF ENGINEER B
OPERATION A, TEST No. 3 (without watch)

Systematic Error ± one S. D., with method deviation
Systematic Error ± one S. D., without method deviation

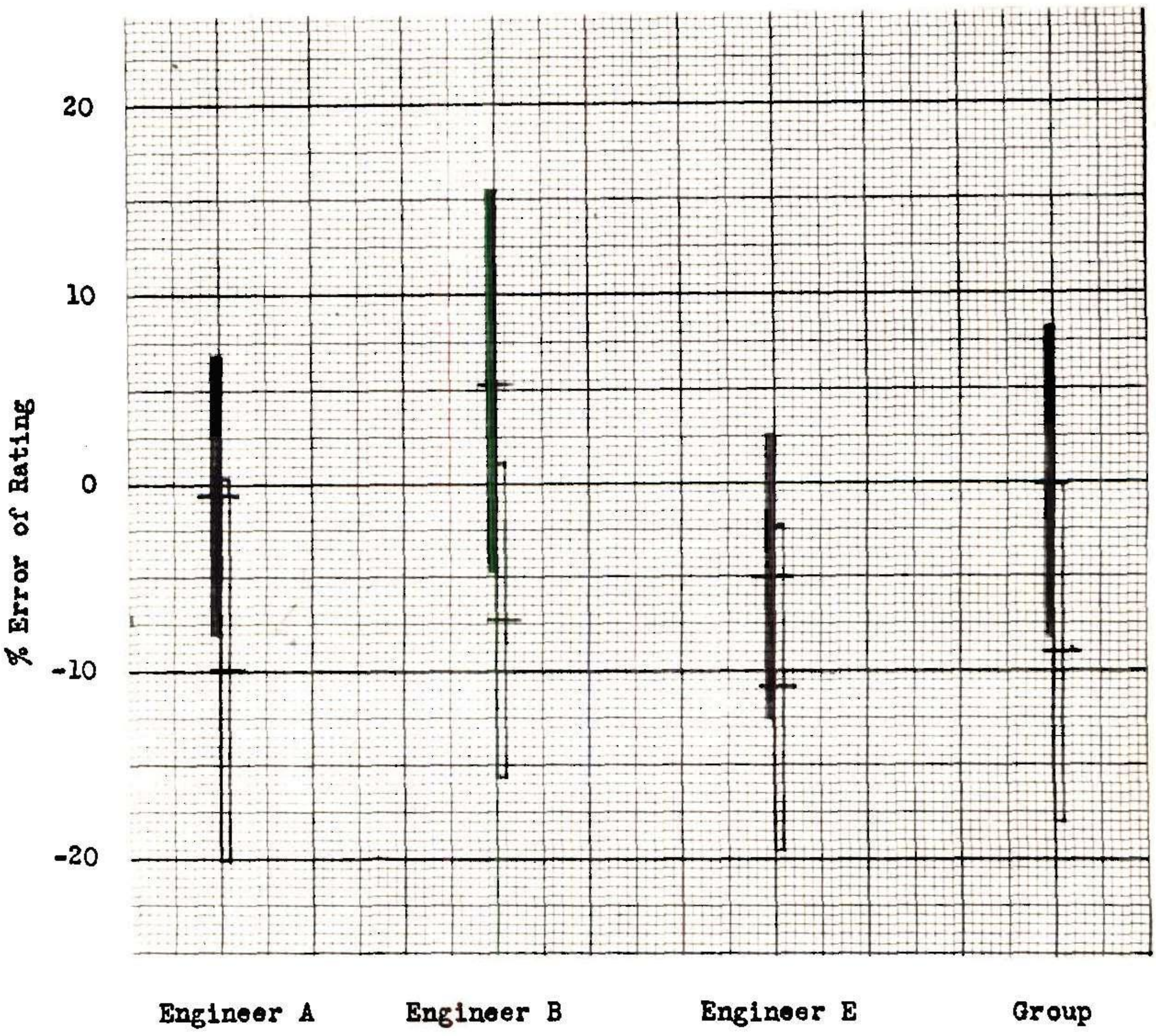

FIGURE 5. SYSTEMATIC ERROR & STANDARD DEVIATION FOR OPERATION B TESTS No. 4 & 5

Systematic Error ± one S. D., with one rating for a cycle

Systematic Error ± one S. D., with two ratings for a cycle

Trend lines were drawn for each engineer with regard to whether or not a watch was used for operation A, and whether one rating or two ratings were assigned for operation B. Figures 6 through 13 contain the trend lines for operation A. Figures 14 through 16 contain the trend lines for operation B.

A review of Figures 1 through 4 reveals that the consistency of the engineer's rating is slightly better for studies not using a stop watch than for studies using one. However, the consistency of rating occasions not containing method deviation is definitely better than those containing it. There is one exception to this made by Engineer B in test 2. The standard deviation of rating non-deviated occasions, in this instance, is considerably smaller than that of deviated occasions. Ratings in which a stop watch was not used tend to have a greater accuracy. The accuracy of rating occasions not containing method deviation is also better than those which do contain it.

It is interesting to note that the two longer elements were rated much lower than normal. It seems that the elaborate contents of the two longer elements may have provided chances for varying speed and also for concealing the skill involved. Missing the dexterity and care necessary for starting a screw, for instance, could have caused engineers to rate too low.

By comparing trend lines in Figures 6 through 13, it is found that for the two longer elements, namely elements 2 and 5, Engineer A has shown a slight improvement of rating in favor of studies not using a stop watch, while Engineer B has reversed the trend; but both differences are insignificant. For the two shorter elements, namely elements 3 and 4, Engineer

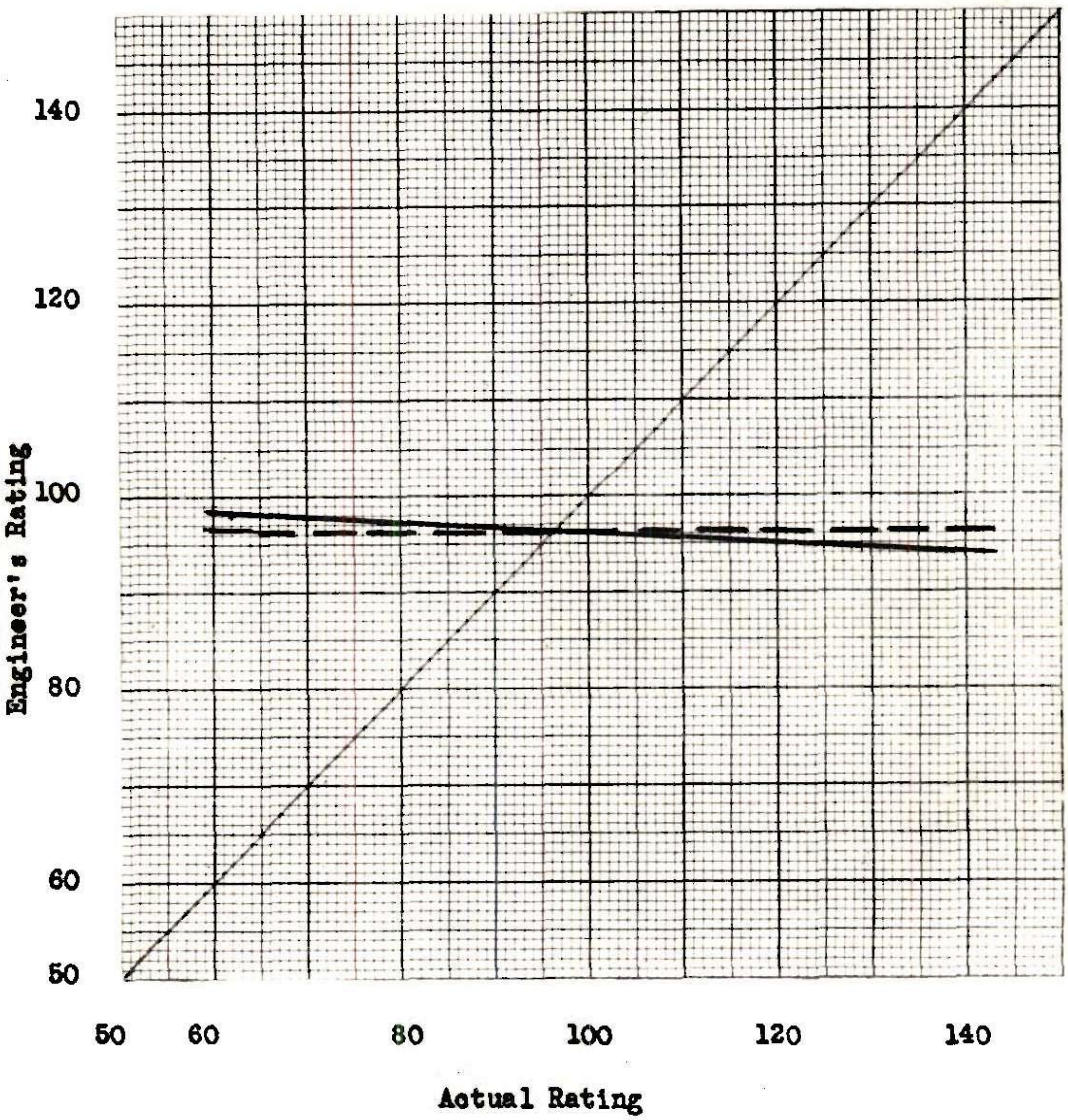

FIGURE 6. TREND LINES OF ENGINEER A FOR ELEMENT 2, OPERATION A

——— Trend line of Test 2, (with watch)

— — — Trend line of Test 3, (without watch)

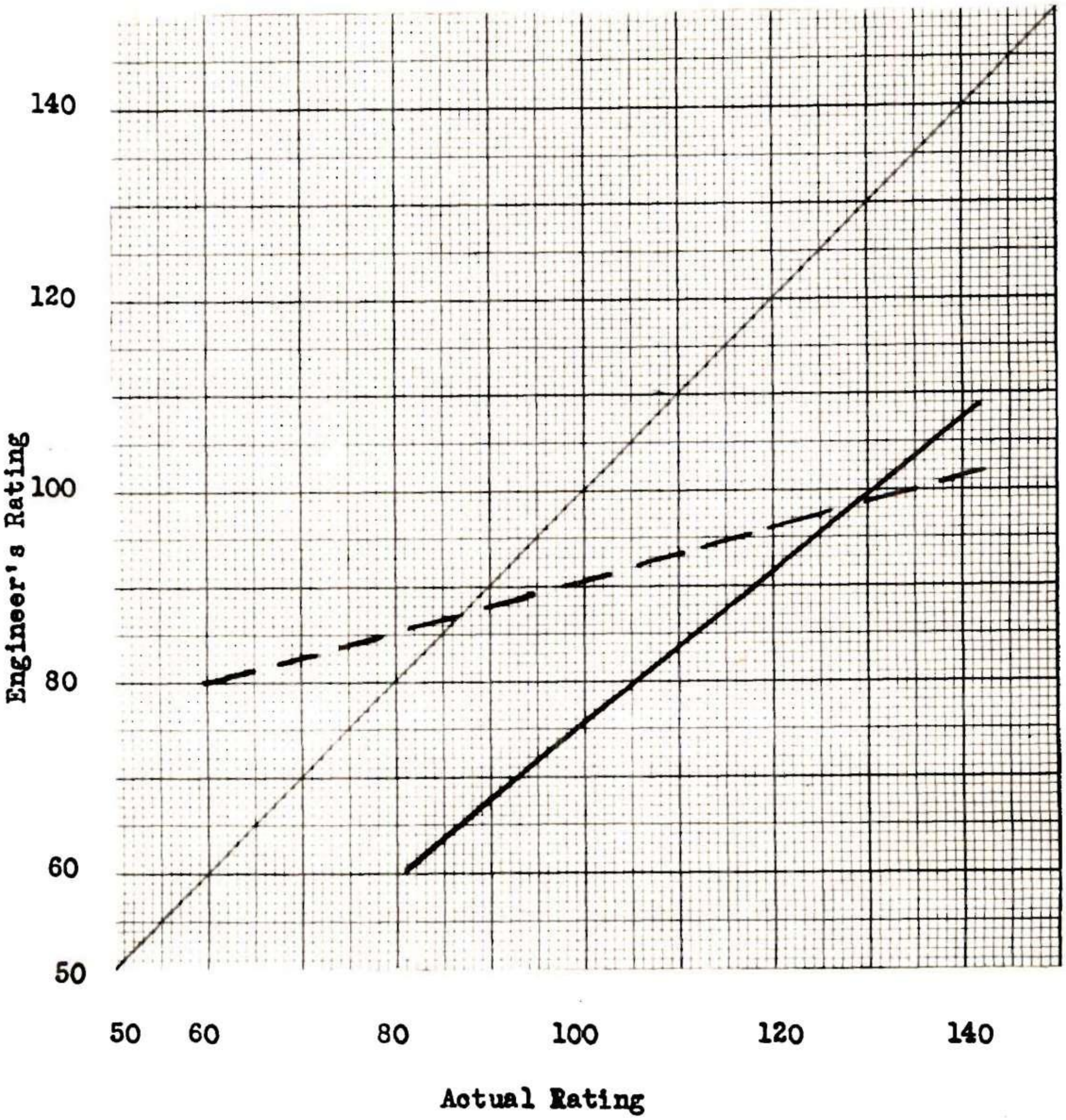

FIGURE 7. TREND LINES OF ENGINEER B FOR ELEMENT 2, OPERATION A

——— Trend line of Test 2,(with watch)

— — — Trend line of Test 3,(without watch)

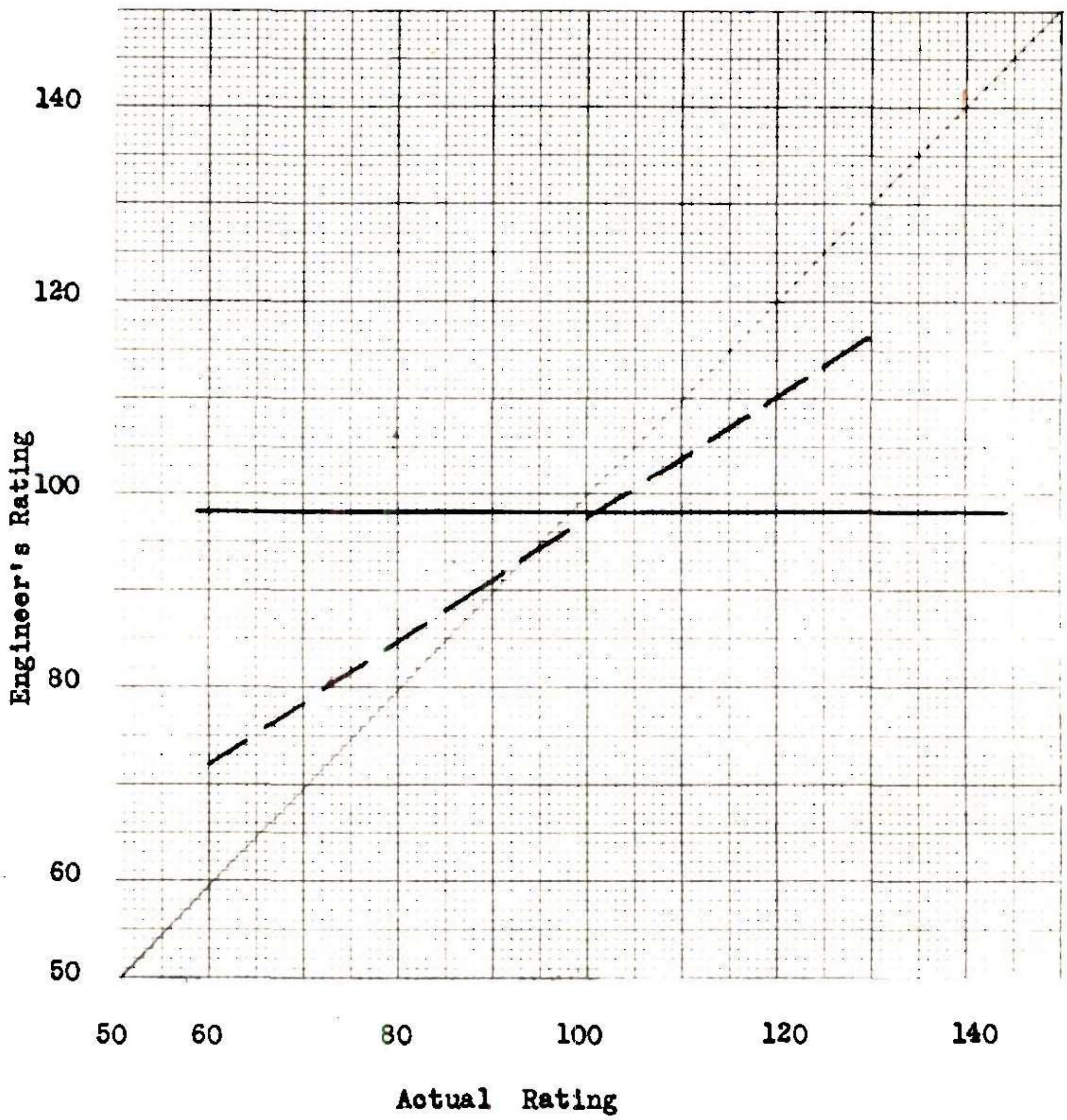

FIGURE 8. TREND LINES OF ENGINEER A FOR ELEMENT 3, OPERATION A

——— Trend line of Test 2, (with watch)

— — — Trend line of Test 3, (without watch)

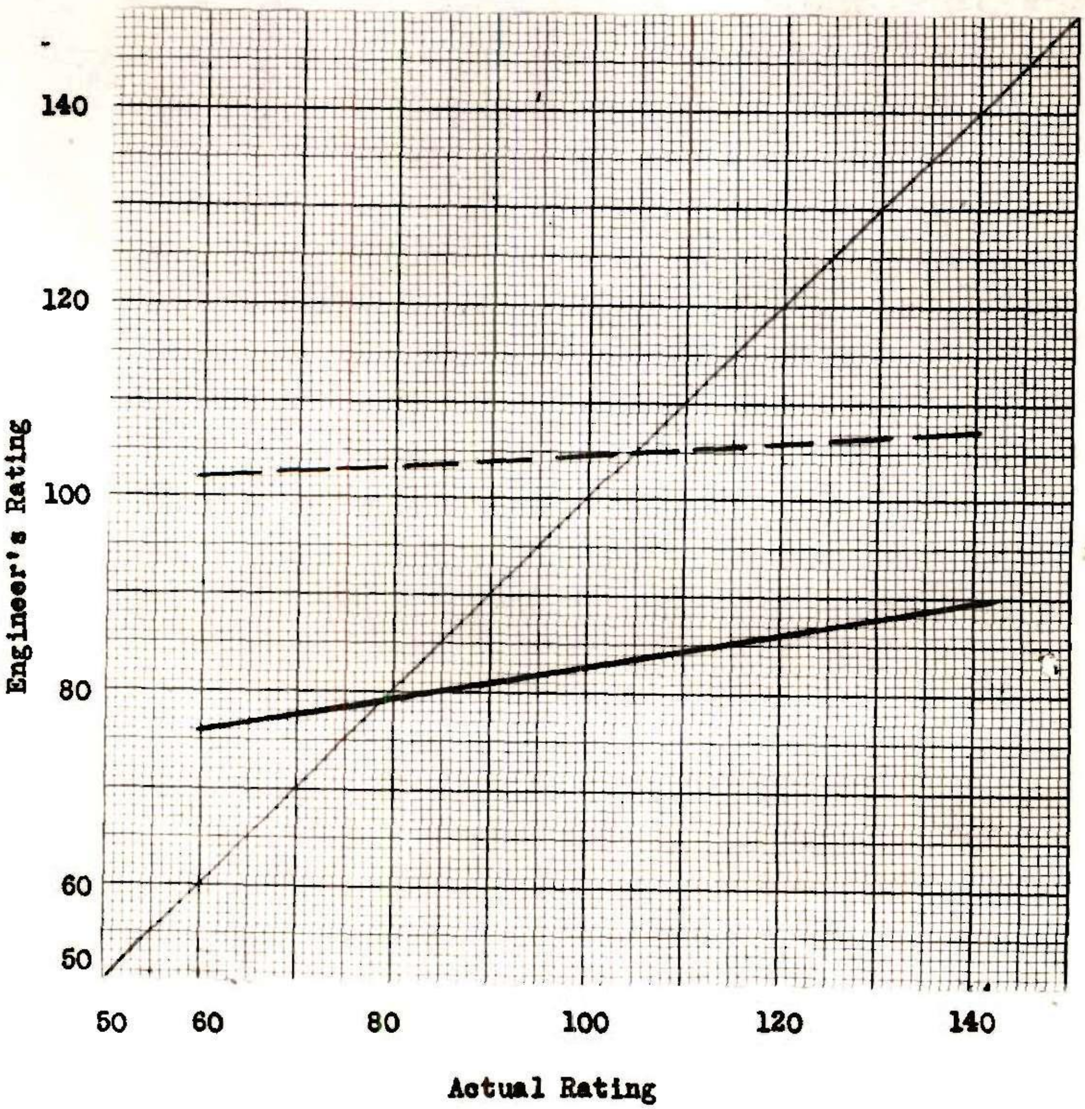

FIGURE 9. TREND LINES OF ENGINEER B FOR ELEMENT 3, OPERATION A

——— Trend line of Test 2,(with watch)

— — — Trend line of Test 3 ,(without watch)

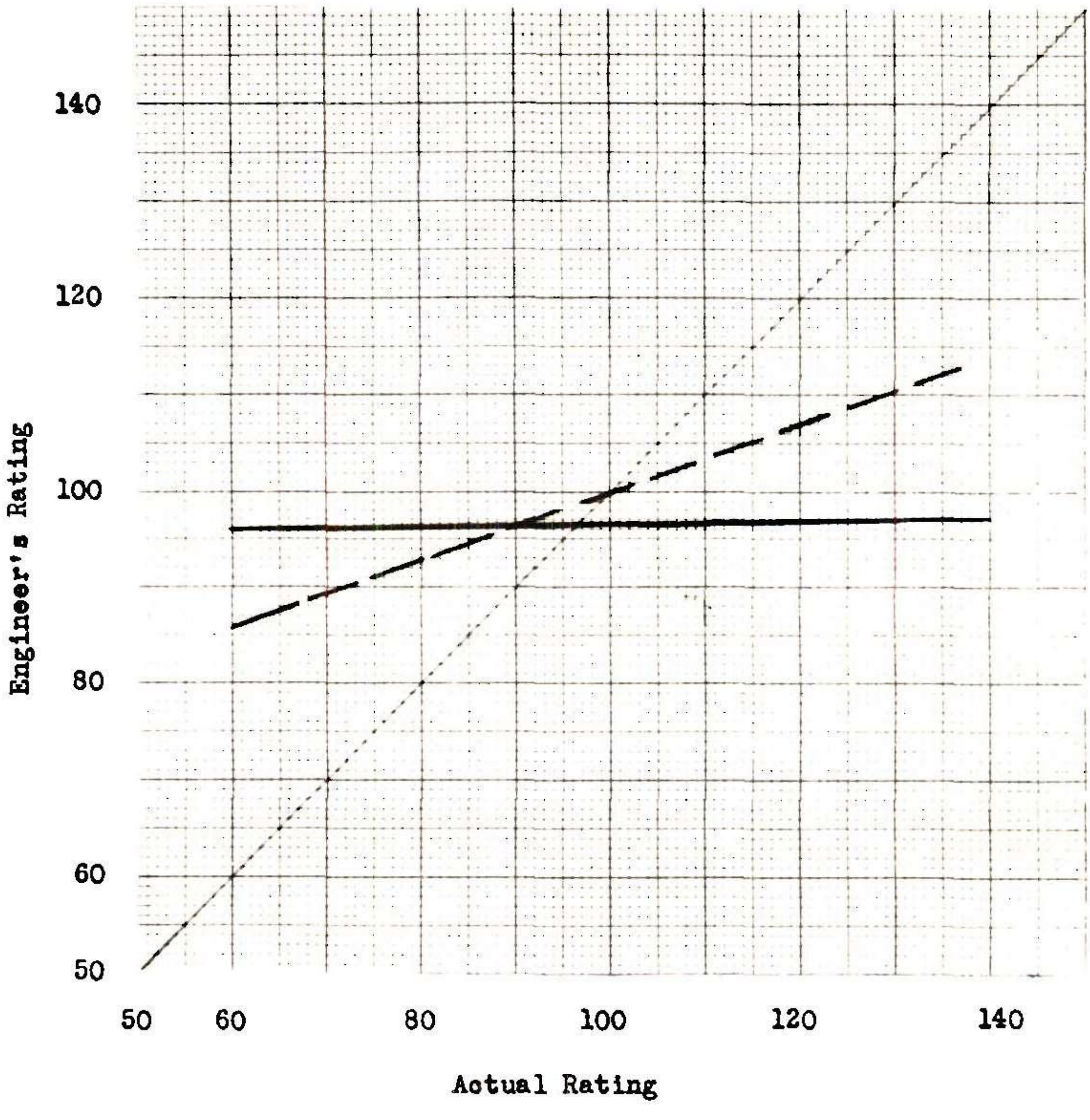

FIGURE 10. TREND LINES OF ENGINEER A FOR ELEMENT 4, OPERATION A

——— Trend line of Test 2,(with watch)

— — — Trend line of Test 3,(without watch)

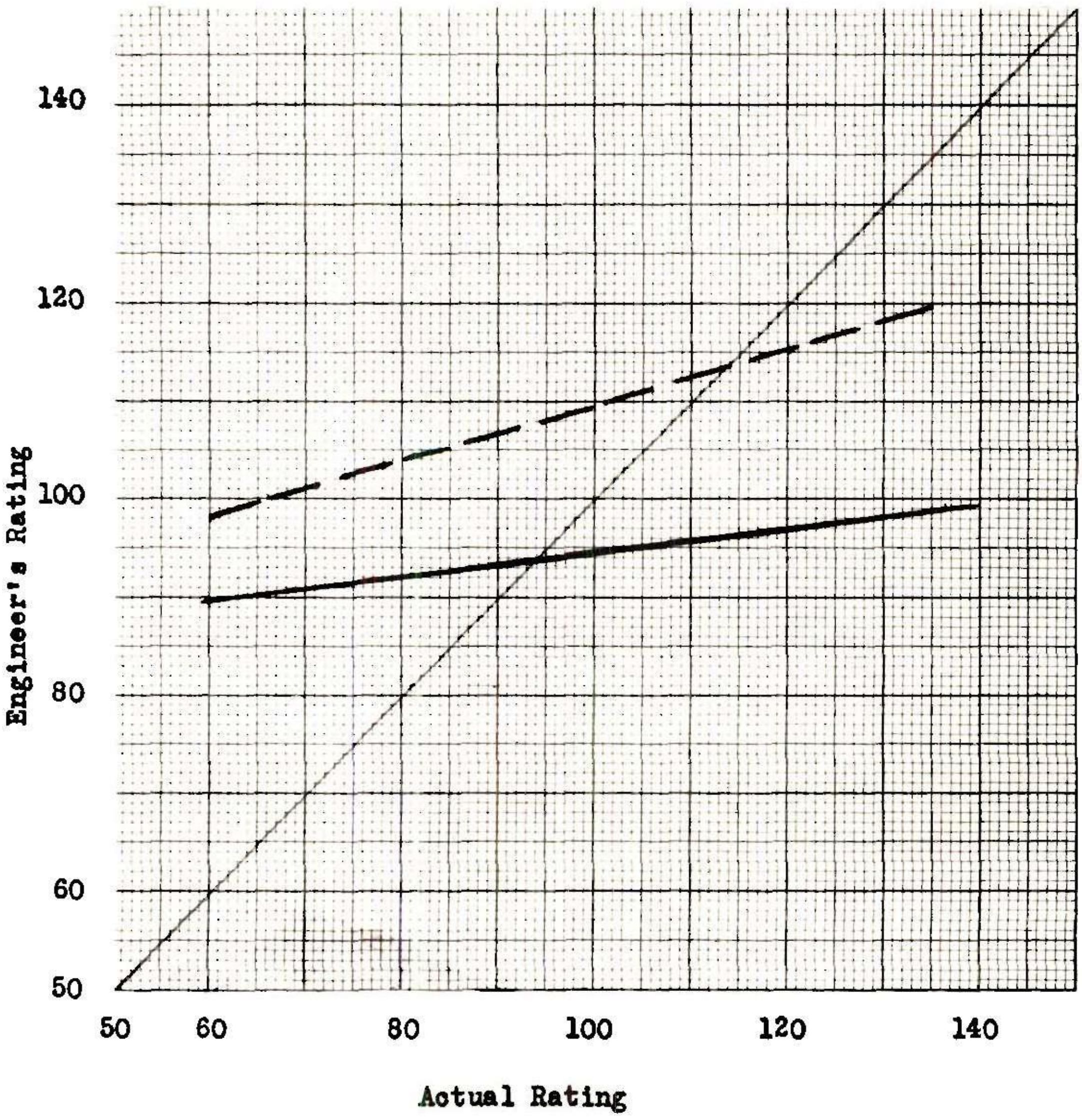

FIGURE 11. TREND LINES OF ENGINEER B FOR ELEMENT 4, OPERATION A

——— Trend line of Test 2, (with watch)

— — — Trend line of Test 3, (without watch)

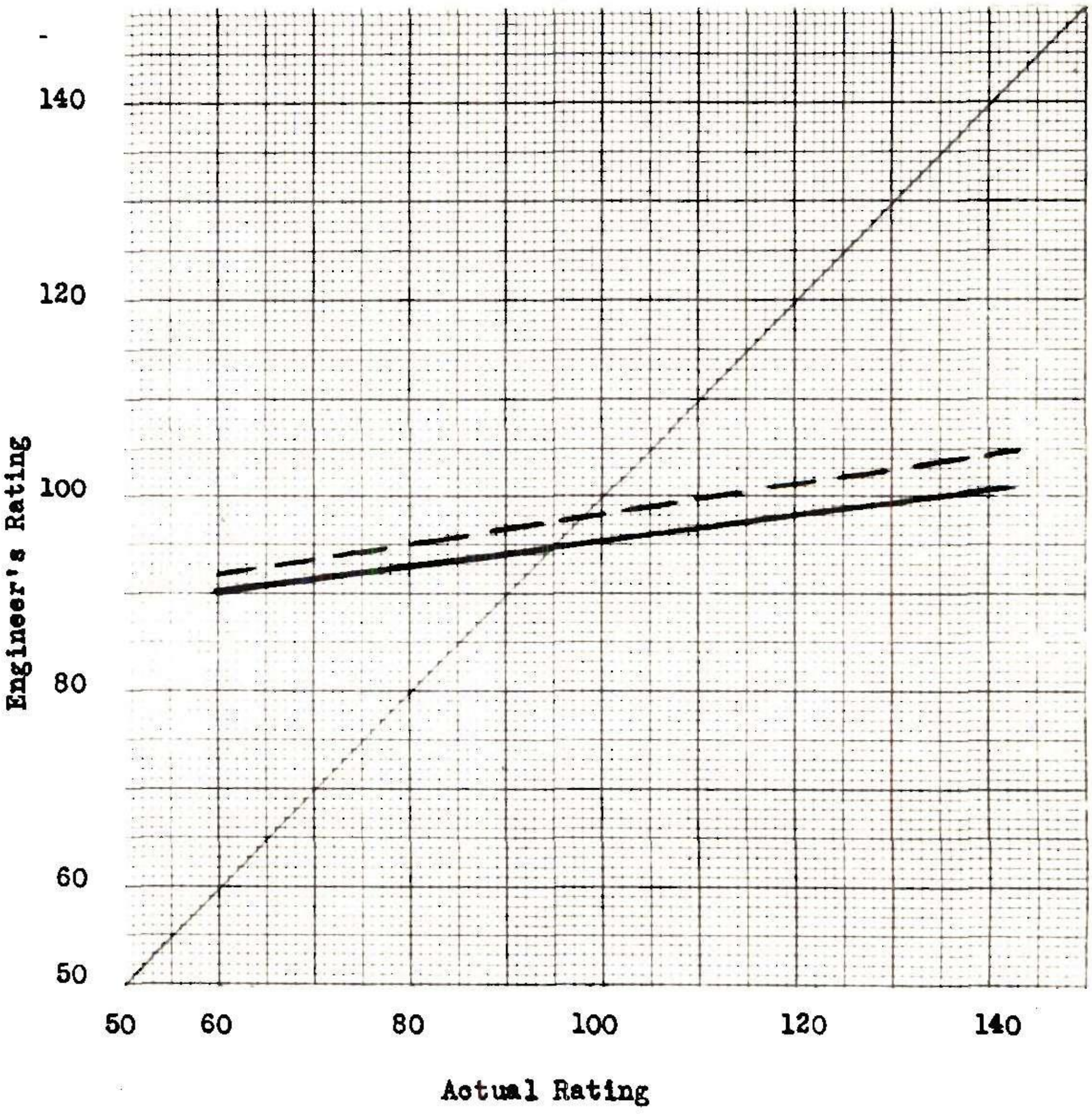

FIGURE 12. TREND LINES OF ENGINEER A FOR ELEMENT 5, OPERATION A

——— Trend line of Test 2,(with watch)

— — — Trend line of Test 3,(without watch)

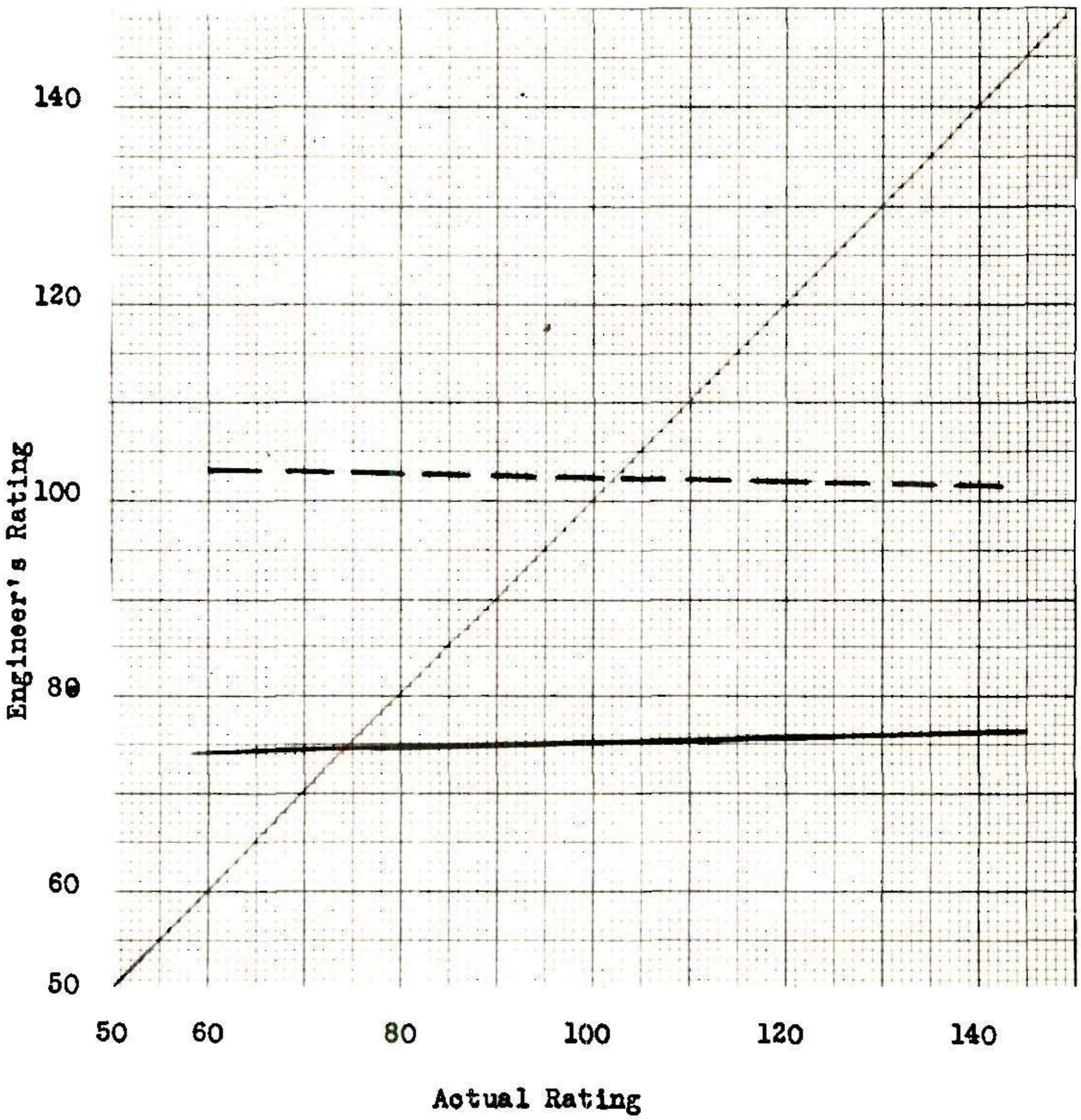

FIGURE 13. TREND LINES OF ENGINEER B FOR ELEMENT 5, OPERATION A

——— Trend line of Test 2,(with waoth)

— — — Trend line of Test 3,(without watch)

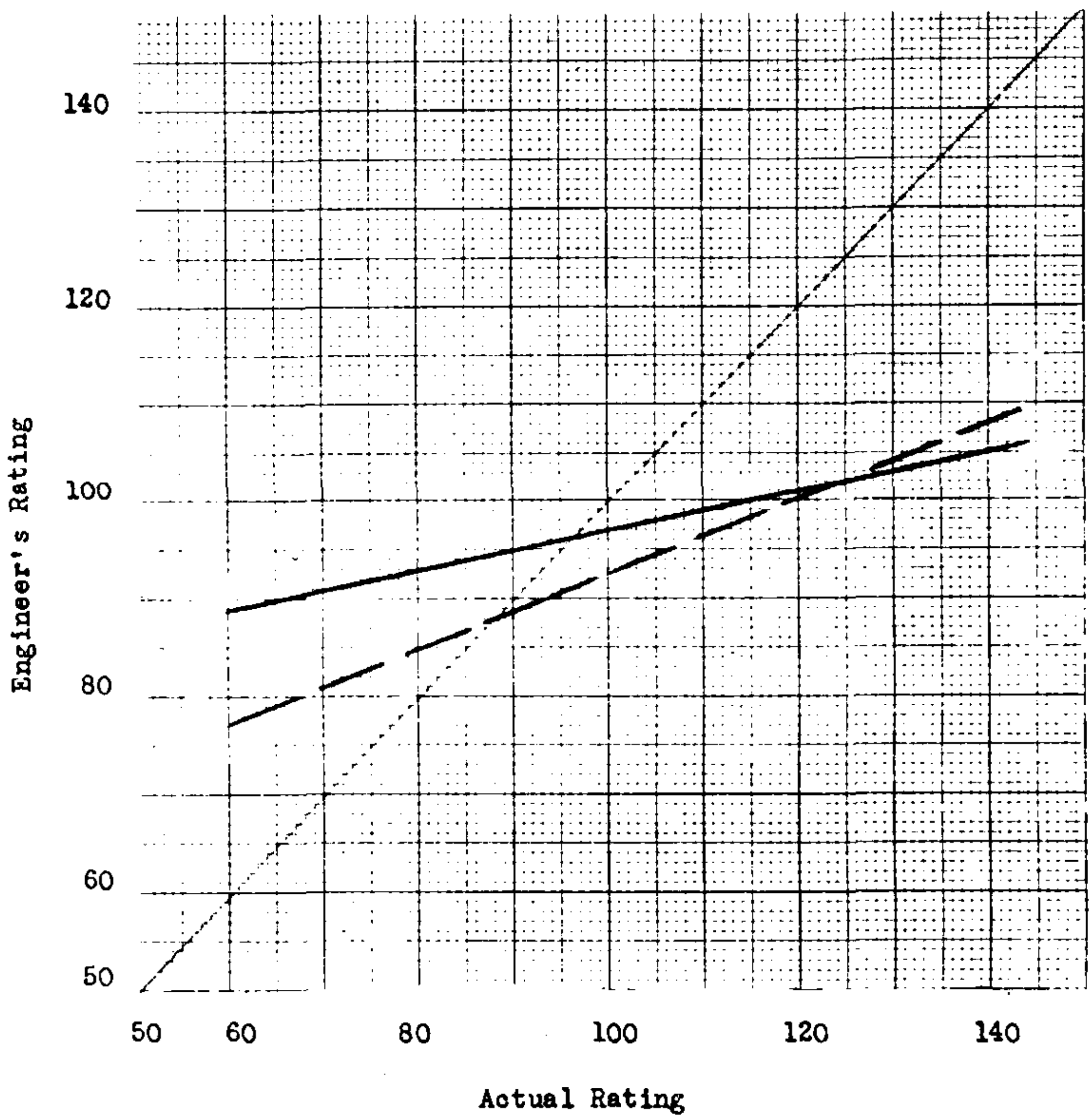

FIGURE 14. TREND LINES OF ENGINEER A, OPERATION B

——— Trend line of Test 4 (one rating)

— — — Trend line of Test 5 (two ratings)

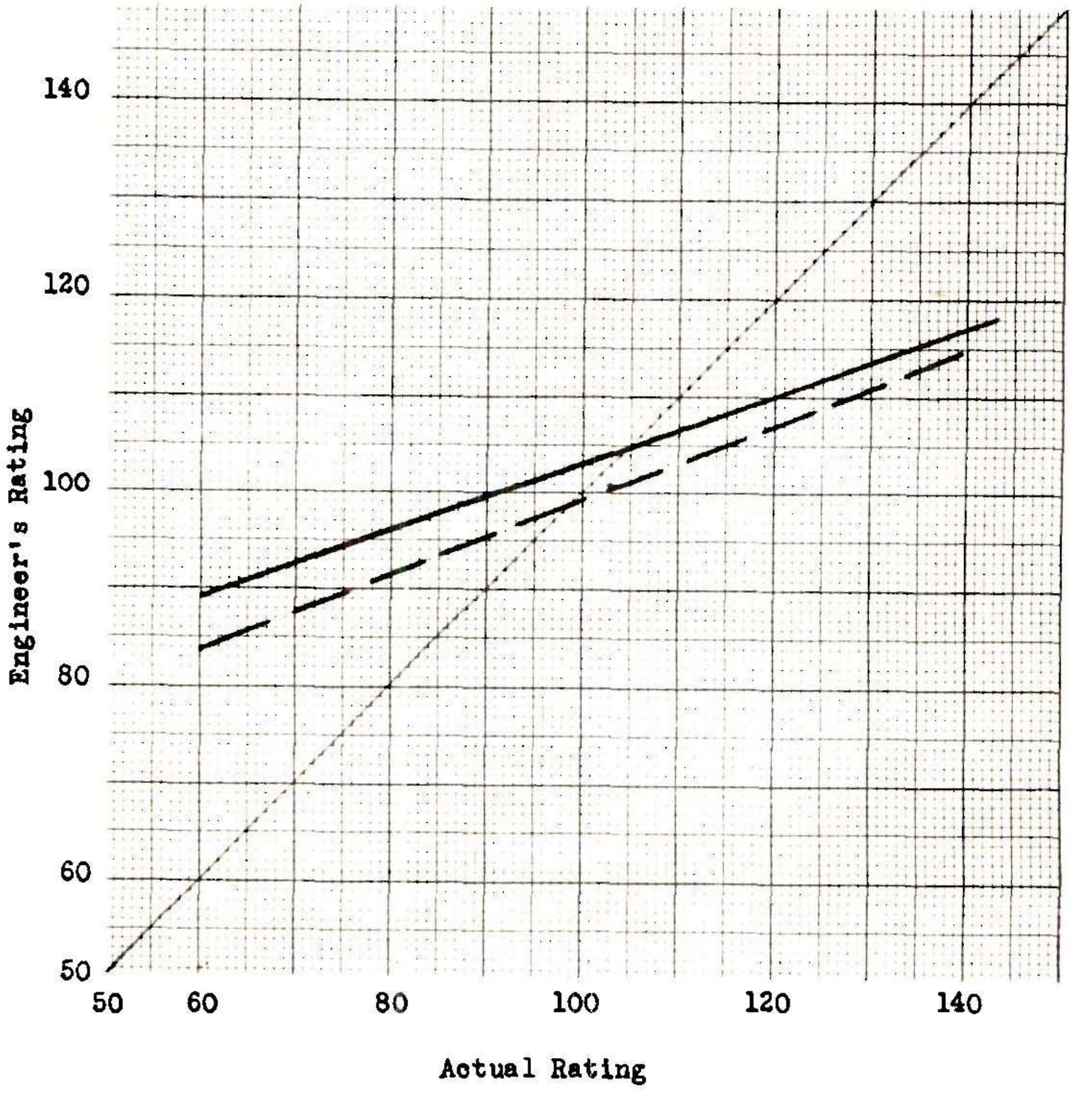

FIGURE 15. TREND LINES OF ENGINEER B, OPERATION B

———— Trend line of Test 4 (one rating)

— — — Trend line of Test 5 (two ratings)

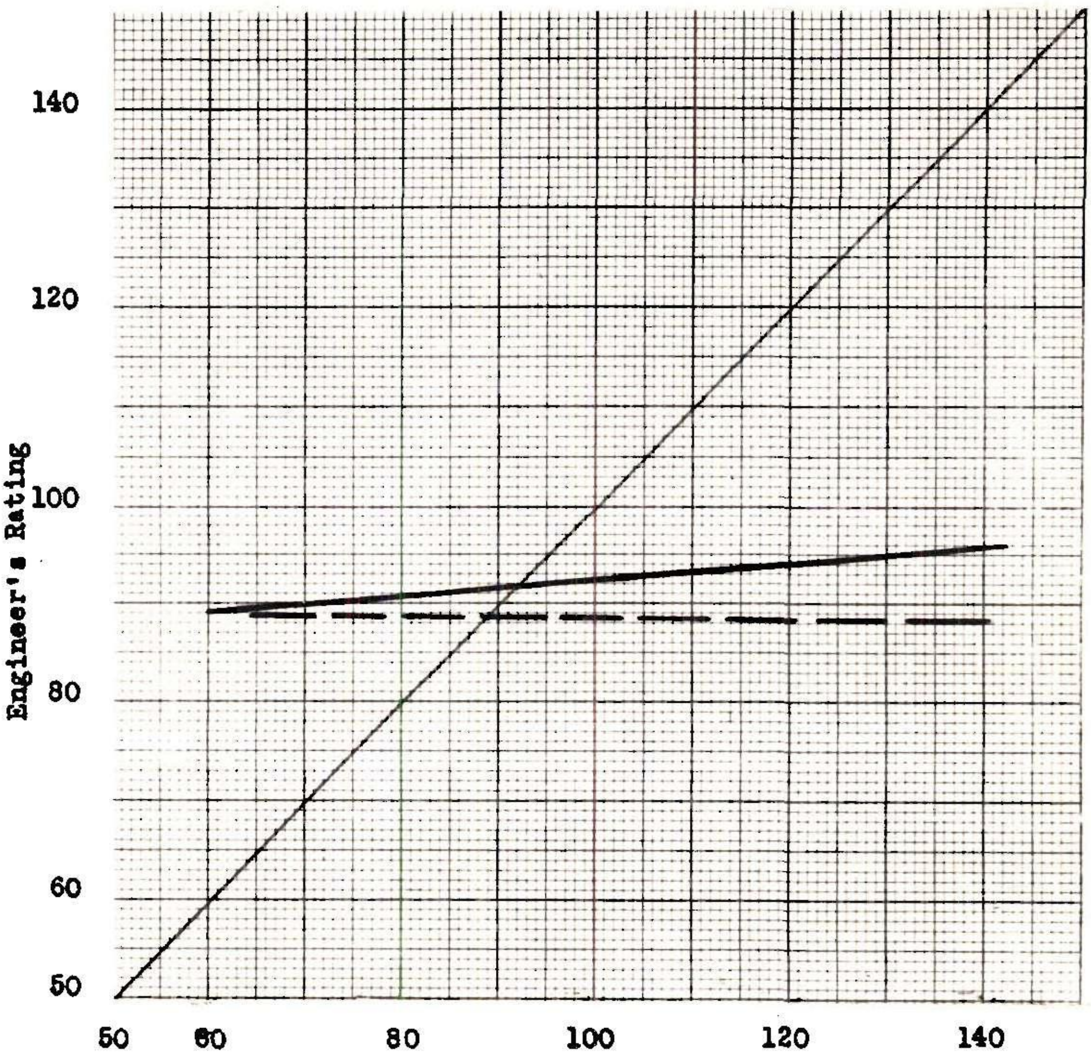

FIGURE 16. TREND LINES OF ENGINEER E, OPERATION B

——— Trend line of Test 4 (one rating)

— — — Trend line of Test 5 (two ratings)

A showed a pronounced improvement of his rating in favor of studies not using a stop watch, while Engineer B showed an improvement in favor of studies not using a stop watch in element 4 and reversed the trend showing a slight favor for studies using a stop watch in element 3.

From a review of Figure 5, it is apparent that the consistency of the engineers' rating is slightly better for the one-rating method, and that the accuracy of rating indicates a significant predominance in accuracy for this method. However, by referring to Figures 14 through 16, the trend lines of Engineer A showed better results in the two-rating method, Engineer B showed no difference and Engineer E showed somewhat better results in the one-rating method. In one-rating or two-rating, all differences among the engineers are insignificant.

All the trend lines in both operations confirm that engineers rated the lower ratings too high and the higher ratings too low, regardless of the effects of the three variables, namely method deviation, stop watch and method of rating. The cause of this phenomenon is probably that engineers are more familiar with normal performance with regard to both speed and method, and a deviation from the normal would cause them to rate high or low. This phenomenon is, however, agreeable with results from other researches.[17]

The better accuracy of the engineers' rating for the one-rating method probably indicates (1) that the engineers are more familiar with the one-rating method which they might have used as a compromise in their

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[17] Report of the Fifth Annual Motion and Time Study Work Session, 1950. (Purdue University, Lafayette, Indiana) p. 16.

daily duties, and (2) that the separation or isolation of the deviated portion of a cycle required engineers to evaluate a deviated method as compared to the standard method. This issue became a matter of guessing, for no known scale has been developed for evaluating method rating accurately and practically.

Table 4 shows the results from analysis of variances for operation A. It shows the systematic error varied mainly due to the effects of W (whether or not a watch was used), E (elements themselves), R x W (the interaction between the raters and the watch), and D x E (interaction between the elements and whether or not method deviation was introduced). These factors were significant to the 0.1% level, which can be interpreted as there being only one chance in a thousand that variations due to those factors could happen by chance. The fact that significant variations occurred according to whether or not a watch was used indicates that engineers rated differently when using a watch than when not using one. This, however, can not be interpreted as proving that one method is better than the other.

The significant variations caused by the elements show that the difficulty of rating different elements are different if method deviations are involved. Thus one element may be more difficult to rate than another. The R x W first order interaction shows that engineers rated differently when using a watch than when not using one, and also differently among themselves. The D x E first order interaction shows that accuracy of rating is different for various elements and also depends upon whether or not method deviation has occurred.

TABLE 4

RESULTS FROM ANALYSIS OF VARIANCES FOR OPERATION A

Source of Variances	Degrees of Freedom	Sum of Squares	Mean Squares	Significance
R	1	13,653.7	13,653.7	**
W	1	64,530.2	64,530.2	***
D	1	7,170.0	7,170.0	**
E	3	282,402.8	94,134.8	***
R x W	1	44,327.7	44,327.7	***
W x D	1	0.4	0.4	---
D x E	3	92,002.1	30,667.3	***
E x R	3	19,486.7	6,495.6	**
E x W	3	16,795.8	5,598.6	**
R x D	1	3,894.1	3,894.1	*
W x D x E	3	16,980.4	5,660.1	**
R x D x E	3	616.3	205.4	---
R x W x E	3	8,916.8	2,972.2	*
R x W x D	1	74.8	74.8	---
Residual	3	4,008.4	1,336.1	
Total	31	574,860.2		

* indicates a significance level of 5%
** indicates a significance level of 1%
*** indicates a significance level of 0.1%
--- indicates interaction is insignificant or non-existent

TABLE 5

RESULTS FROM ANALYSIS OF VARIANCES FOR OPERATION B

Source of Variances	Degrees of Freedom	Sum of Squares	Mean Square	Significance
R	2	4,229.4	2,114.7	---
M	1	12,060.2	12,060.2	*
Residual	2	1,377.3	688.4	
Total	5	17,666.9		

* indicates a significance level of 5%

--- indicates interaction is insignificant or non-existent

To a lesser significance level, the factors R (raters), D (whether deviation was introduced), E x R (interaction between elements and raters), E x W (interaction between elements and watch) and W x D x E (interaction among watch, deviation and elements) contributed variances. These factors are significant to a level of 1%. The variation caused by raters indicates that there was a considerable difference of opinion among the engineers in judging how far away the performance observed was from normal. The systematic error also varied due to the presence or absence of method deviation.

The first order interaction E x R indicates that if engineers were to rate various elements, the accuracy would vary for different elements and among different engineers. Similarly, E x W interaction indicates that accuracy would vary for different elements and for whether or not a watch was used. The second order interaction W x D x E indicates that accuracy of rating would vary according to whether or not a watch was used, the presence or absence of deviation and the nature of the different elements.

The R x D and R x W x E interactions showed a weak 5% significance level. However, they probably both exist. The R x D interaction indicates that the accuracy of rating is different for different raters and also different for the presence or absence of deviation. The R x W x E interaction indicates that if engineers were to rate various elements, the accuracy would vary according to whether or not a watch was used and that it would vary among the raters.

By referring to Table 5 for the results from the analysis of variances for operation B, one finds that between the two factors R (raters) and M (methods of rating) only M is significant to the 5% level. This indicates that the use of one-rating and two-rating methods is different in accuracy while there is no significant difference among the raters.

The residual which corresponds to the experimental errors is greater for operation A than for operation B. It should be pointed out that in operation A at least one second order interaction is significant. Therefore, the results can not be considered satisfactory owing to the limited number of degrees of freedom.

CHAPTER VI

SUMMARY AND CONCLUSION

There are certain limitations in drawing a conclusion from this thesis. First of these is the limited number of time study engineers involved as subjects of this study. Secondly, the engineers had only limited familiarity with the operations being studied. Although engineers had been shown several cycles of normal operation prior to each test, they probably were still less familiar with the operation being studied than those they had observed from day to day. The third limitation is that the different speeds an operator might have adopted in duplicating some part of an operation (for instance, test 3 was a duplicate of test 4) may have complicated the task of rating for the engineers, although the extent of method deviation was rigidly controlled.

The following conclusion was drawn within the preceding limitations:

(1) The ratings assigned by engineers using a stop watch are different from those not using one.

(2) The accuracy of rating is slightly better when rating only is required than when timing and rating are both required.

(3) The consistency of rating is slightly better when rating only is required than when timing and rating are both required.

(4) Both the accuracy and consistency of rating are better in the case of the absence of method deviation than in the presence of method deviation.

(5) The engineers rated low ratings too high and rated high ratings too low.

(6) The writer does not feel qualified to evaluate the elemental length in regard to the accuracy and consistency of rating, whether or not a stop watch is used or whether or not method deviation is present.

(7) The effort of separating a deviated portion of a cycle from the rest of that cycle is not favored. This, however, should be considered along with the fact that engineers are much less familiar with the two-rating method tried in this study than with the customary method of rating.

(8) It is suggested that further research be conducted in developing a scale that will guide time study engineers to obtain method rating accurately and practically.

APPENDIX I

TABLE 6

RATINGS BY ENGINEER A, TEST NO. 1, OPERATION A

Cycle Number	Elements 1	2	3	4	5
1	100	100	100	100	90
2	90	95	100	100	100
3	100	100	110	100	110
4	100	95	90	110	110
5	100	90	100	110	105
6	110	100	110	115	100
7	105	110	100	110	110
8	110	110	110	110	100
9	105	90	100	100	110
10	110	100	110	110	105
11	105	100	115	105	100
12	100	100	100	100	95

RATINGS BY ENGINEER A, TEST NO. 1, OPERATION B

Cycle Number	Elements 1	2	3	4
1	100	100	90	100
2	100	90	95	100
3	100	100	100	100
4	110	100	110	100
5	100	100	90	100
6	100	100	100	100
7	100	100	95	100
8	100	90	110	100
9	100	110	110	110
10	110	110	110	100
11	100	100	90	100
12	100	100	95	100
13	90	100	90	110
14	110	110	110	110
15	110	110	110	110
16	110	110	110	110
17	100	100	100	100
18	100	100	110	100

TABLE 7

RATINGS BY ENGINEER B, TEST NO. 1, OPERATION A

Cycle Number	Elements 1	2	3	4	5
1	70	50	60	70	60
2	65	55	65	70	60
3	65	55	65	65	65
4	60	55	60	70	65
5	65	55	70	70	65
6	65	55	65	65	65

RATINGS BY ENGINEER B, TEST NO. 1, OPERATION B

Cycle Number	Elements 1	2	3	4
1	70	70	70	70
2	70	70	70	70
3	70	70	70	70
4	70	70	70	70
5	65	65	55	65
6	70	70	70	70
7	65	65	55	65
8	75	70	60	70
9	65	70	60	65
10	70	70	75	70
11	70	70	70	70
12	70	70	60	70
13	70	70	60	70
14	70	75	65	75
15	70	70	70	70
16	75	70	70	70
17	70	70	70	70
18	70	60	55	70

* 60 was designated as normal.

TABLE 8

RATINGS BY ENGINEER C, TEST NO. 1, OPERATION A

Cycle Number	Elements 1	2	3	4	5
1	95	90	100	105	105
2	105	95	105	110	110
3	105	95	110	115	110
4	110	110	110	120	115
5	110	110	110	115	110
6	115	115	120	115	110
7	115	110	125	115	110
8	110	105	110	115	115
9	115	110	115	105	110
10	110	105	105	115	105
11	105	110	115	110	110
12	110	110	100	120	110

RATINGS BY ENGINEER C, TEST NO. 1, OPERATION B

Cycle Number	Elements 1	2	3	4
1	100	90	100	100
2	100	95	90	100
3	100	95	90	100
4	100	105	95	100
5	105	110	95	105
6	110	100	100	100
7	110	110	95	105
8	105	105	95	100
9	105	105	100	110
10	110	110	105	110
11	110	115	105	110
12	100	100	90	105
13	105	105	95	110
14	105	110	105	110
15	105	105	110	110
16	105	110	100	110
17	105	110	105	110
18	105	110	105	110

TABLE 9

RATINGS BY ENGINEER A, TEST NO. 2, OPERATION A

With watch

Cycle Number	Elements 1	2	3	4	5
1	100	95	100	85	95
2	100	100	90	90	100
3	100	95	100	90	100
4	100	95	100	100	95
5	100	90	95	100	100
6	100	95	100	95	100
7	100	100	100	95	100
8	100	95	95	100	100
9	100	100	100	100	100
10	100	95	100	100	95
11	100	95	?	100	?
12	100	100	100	90	100
13	100	95	95	100	95
14	100	95	100	100	95
15	100	90	100	100	100
16	100	95	95	90	100
17	100	100	100	95	100

RATINGS BY ENGINEER B, TEST NO. 2, OPERATION A

With watch

Cycle Number	Elements 1	2	3	4	5
1	100	95	85	95	80
2	100	80	80	90	80
3	100	100	90	95	90
4	100	75	85	95	80
5	100	95	85	95	95
6	100	100	90	95	95
7	100	75	80	90	75
8	100	75	80	95	80
9	100	95	80	95	80
10	100	75	80	95	80
11	100	75	80	90	70
12	100	75	80	90	70
13	100	70	70	90	80
14	100	75	80	95	80
15	100	95	80	100	100
16	100	95	80	90	70
17	100	75	90	90	80

TABLE 10

RATINGS BY ENGINEER A, TEST NO. 3, OPERATION A

Without watch

Cycle Number	Elements 1	2	3	4	5
1	100	90	110	90	100
2	95	100	90	90	100
3	110	100	100	100	95
4	95	100	90	100	95
5	95	90	90	100	100
6	100	100	100	90	100
7	100	100	90	90	100
8	100	90	100	100	95
9	95	100	90	100	95
10	100	90	90	100	100
11	100	90	110	95	100
12	95	105	90	100	100
13	100	95	105	110	100
14	95	100	90	100	95
15	100	95	90	110	105
16	95	95	110	90	105
17	100	100	110	90	110

RATINGS BY ENGINEER B, TEST NO. 3, OPERATION A

Without watch

Cycle Number	Elements 1	2	3	4	5
1	110	85	110	110	115
2	110	95	110	110	100
3	110	95	110	105	110
4	110	105	115	115	100
5	105	100	110	110	110
6	110	85	105	95	105
7	110	95	105	95	90
8	105	90	100	115	110
9	110	90	110	115	90
10	105	85	110	110	105
11	110	85	110	90	110
12	110	85	90	110	100
13	105	95	110	110	100
14	90	90	95	105	95
15	105	85	100	105	100
16	95	90	100	110	100
17	110	95	100	100	110

TABLE 11

RATINGS FROM TEST NO. 4, OPERATION B

One-rating Method

Cycle Number	Engineer A	Engineer B	Engineer E*
1	90	90	78
2	95	105	86
3	100	95	93
4	90	85	86
5	95	105	86
6	90	110	86
7	110	90	93
8	95	90	89
9	95	100	93
10	95	105	93
11	100	115	97
12	95	100	93
13	110	105	97
14	90	95	93
15	95	110	97
16	100	110	93
17	100	110	100
18	90	100	97
19	100	110	97
20	95	115	97

* Engineer E designated 60 as normal level. The values shown here have been converted to 100% as normal.

TABLE 12

RATINGS FROM TEST NO. 5, OPERATION B
Two-rating Method

Cycle Number	Engineer A R_d	Engineer A R_n	Engineer A R_e	Engineer B R_d	Engineer B R_n	Engineer B R_e	Engineer E R_d	Engineer E R_n	Engineer E R_e
1	60	100	91.2	95	100	98.4	93	100	98.4
2	70	95	90.3	75	100	93.5	89	97	94.9
3	80	100	94.1	90	105	100.5	93	93	72
4	50	100	69.7	60	100	75.7	83	97	88.5
5	75	95	82.5	90	105	95.6	93	97	94.5
6	50	100	67.3	50	100	67.3	83	97	87.7
7	60	95	87.6	75	100	94.7	?	97	?
8	70	110	90.8	80	95	91.5	93	97	96.1
9	60	110	98.9	90	110	105.5	93	93	93
10	70	110	102	85	105	101	86	93	91.6
11.	80	100	96.7	80	105	100.9	?	93	?
12	60	100	76.5	85	110	95.4	83	93	87.1
13	50	100	75.1	80	110	95	86	97	91.5
14	70	95	80.3	85	90	87	86	89	87.2
15	80	95	91.4	60	95	86.6	83	86	85.3
16	50	100	90.4	60	105	96.4	80	93	90.5
17	75	110	104.2	90	105	102.5	83	89	88
18	75	100	?	90	110	106.6	80	89	87.5
19	?	100	?	50	110	76.8	83	93	87.4
20	80	100	89	60	100	78	83	86	84.3

R_d Rating for deviated portion of a cycle

R_n Rating for non-deviated portion of a cycle

R_e Equivalent overall rating for the cycle

APPENDIX II

APPENDIX II

ELEMENTAL DESCRIPTION

OPERATION A

Element No.	Left Hand	Right Hand
1	Grasp roller on extreme right of roller supply	----
	Grasp one journal block transport to jig	Grasp one journal block transport to jig
	Align journal hole with roller pin so that threaded journal holes are in top position	Same as left hand
	Assemble journal with roller	Same as left hand

Element 1 ends with fingers of both hands release journal blocks.

Element No.	Left Hand	Right Hand
2	Grasp frame and transport to jig,align	Same as left hand
	Pick up four machine screws,palm screws & assist right hand in aligning threaded holes in frame	Take screw head and align screw with hole
	Assist right hand	Start screw in threaded hole with four 45 degree turns
	Repeat the above operations for the other journal block	Repeat the above operations for the other journal block

Element 2 ends with fingers of both hands release last screw.

Element No.	Left Hand	Right Hand
3	----	Get Yankee screw driver from holder
	Grasp guide sleeve,position bit in closest screw slot to the holder	Hold screw driver

ELEMENTAL DESCRIPTION

OPERATION A (continued)

Element No.	Left Hand	Right Hand
3	Hold guide sleeve	Drive Yankee screw driver, average five strokes
	Repeat the above operation for both left hand and right hand on the next screw on the same journal block, then repeat the same on the other journal block.	
	Element 3 ends with right hand put back the screw driver.	
4	Get wood board, transport to and position in frame	Same as left hand
	Grasp one flat head machine screw and insert it in board hole nearest to the holder	Same as left hand
	Repeat the above operation for both hands in clockwise direction till all eight screws are in place	
	Element 4 ends with fingers release last pair of screws.	
5	Grasp guide sleeve of screw driver and position in screw slot	Move screw driver to right upper corner of board
	Assist right hand	Drive screw driver, average two strokes
	Repeat the above for both hands in the direction as in Element 4	
	----	Put back screw driver
	Both hands get finished dolly, transport aside to the finished dolly stack	
	Element 5 ends with sound of released finished dolly contacting stack of dolly.	

ELEMENTAL DESCRIPTION

OPERATION B

Element No.	Left Hand	Right Hand
1	Get U-bolt and position in jig with threaded ends up	Same as left hand

Element 1 ends with fingers release both U-bolts.

2	Get clip and place over U-bolt with groove down	Same as left hand

Element 2 ends with fingers release clips.

3	Get one nut and assemble to the U-bolt stud nearer to operator,average three turns	Same as left hand

Repeat the above on the other two studs

Element 3 ends with fingers release last pair of nuts.

4	Grasp assembly and place in finished work bin	Same as left hand

Element 4 ends with sound of completed assembly contacting finished work bins.

Two wire rope clip assemblies were assembled simultaneously.

APPENDIX III

APPENDIX III

METHOD DEVIATIONS FOR OPERATION A

Element 2: Pick up each screw individually.

Element 3: Use half stroke instead of full stroke.

Element 4: Pick up approximately twelve flat head screws, hold in one hand while the other hand insert them into holes individually.

Element 5: Remove assembly from jig, turns it over and inspect it for approximately .03 minutes.

METHOD DEVIATIONS FOR OPERATION B

Element 1: Blind grasp of U-bolt followed by pause and prepositioning.

Element 2: Up side down assembly of one clip and followed by correction.

Element 3: Non-simultaneous assembly of nuts to studs on both pair of U-bolts.

APPENDIX IV

APPENDIX IV

NORMAL TIME VALUES FOR OPERATION A

Element No.	Normal Time
1	.1038
2	.4518
3	.2803
4	.2283
5	.4259
Cycle	1.4901 minutes

NORMAL TIME VALUES FOR OPERATION B

Element No.	Normal Time
1	.0418
2	.0469
3	.1457
4	.0188
Cycle	.2532 minutes

APPENDIX V

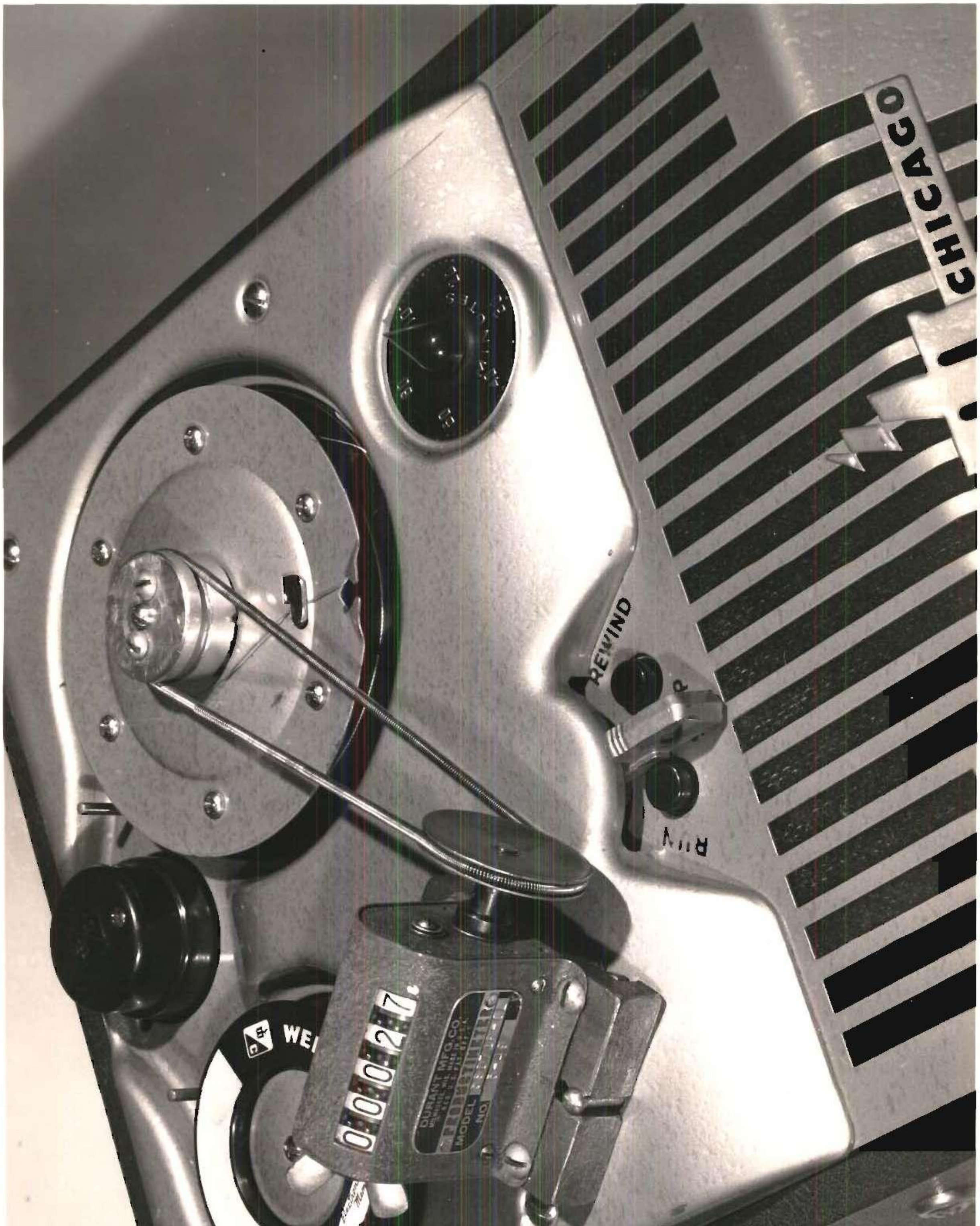
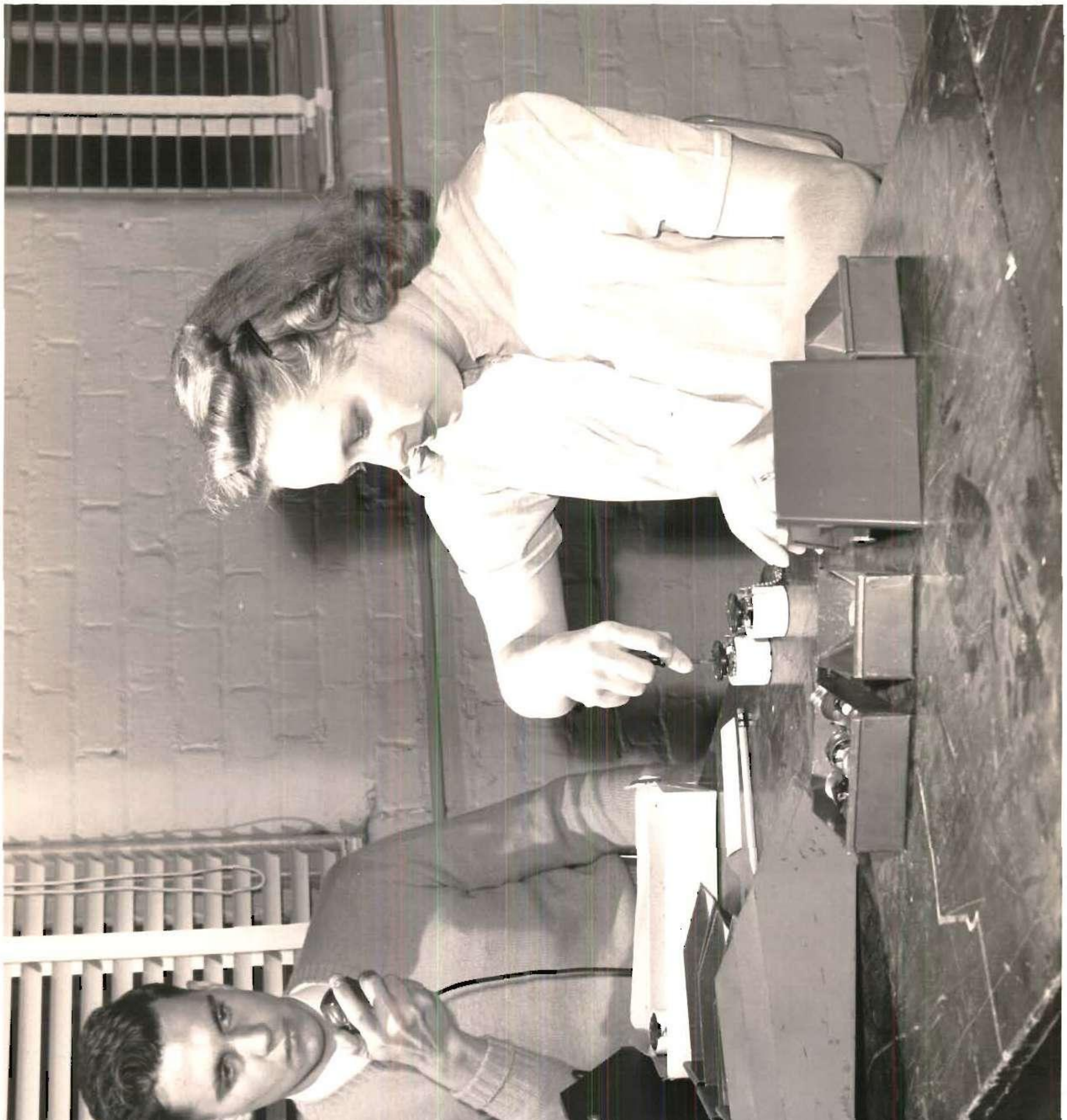


FIGURE 17 AN MAGNETIC WIRE RECORDER



MAKING A TRANSCRIBED TIME STUDY

APPENDIX VI

FIGURE 18 LAYOUT OF WORK PLACE OF OPERATION A

FIGURE 19   LAYOUT OF WORK PLACE OF OPERATION B

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BIBLIOGRAPHY

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